THE PEOPLE OF THE STATE OF NEW YORK,
Complainants,

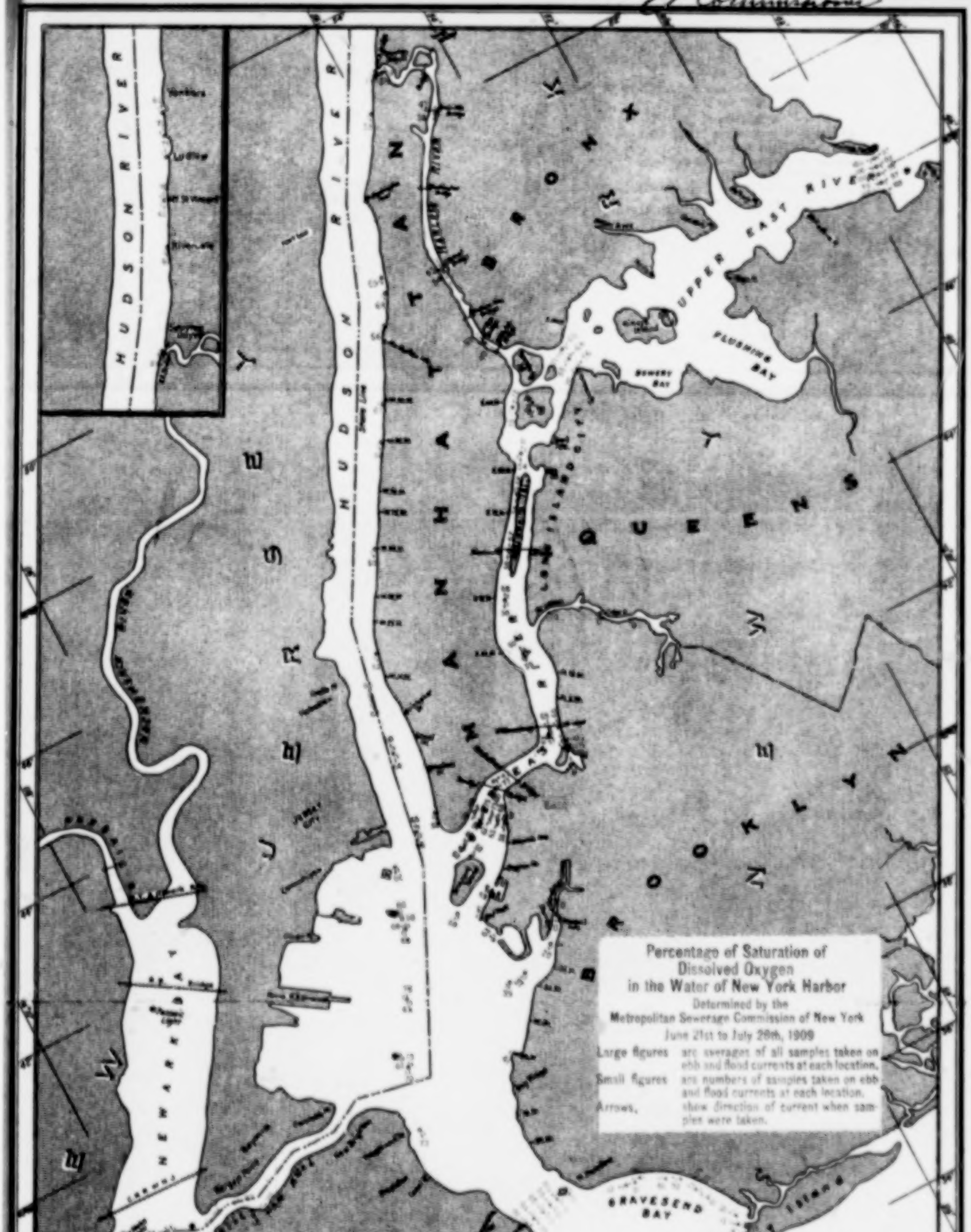
vs.

STATE OF NEW JERSEY ET AL.

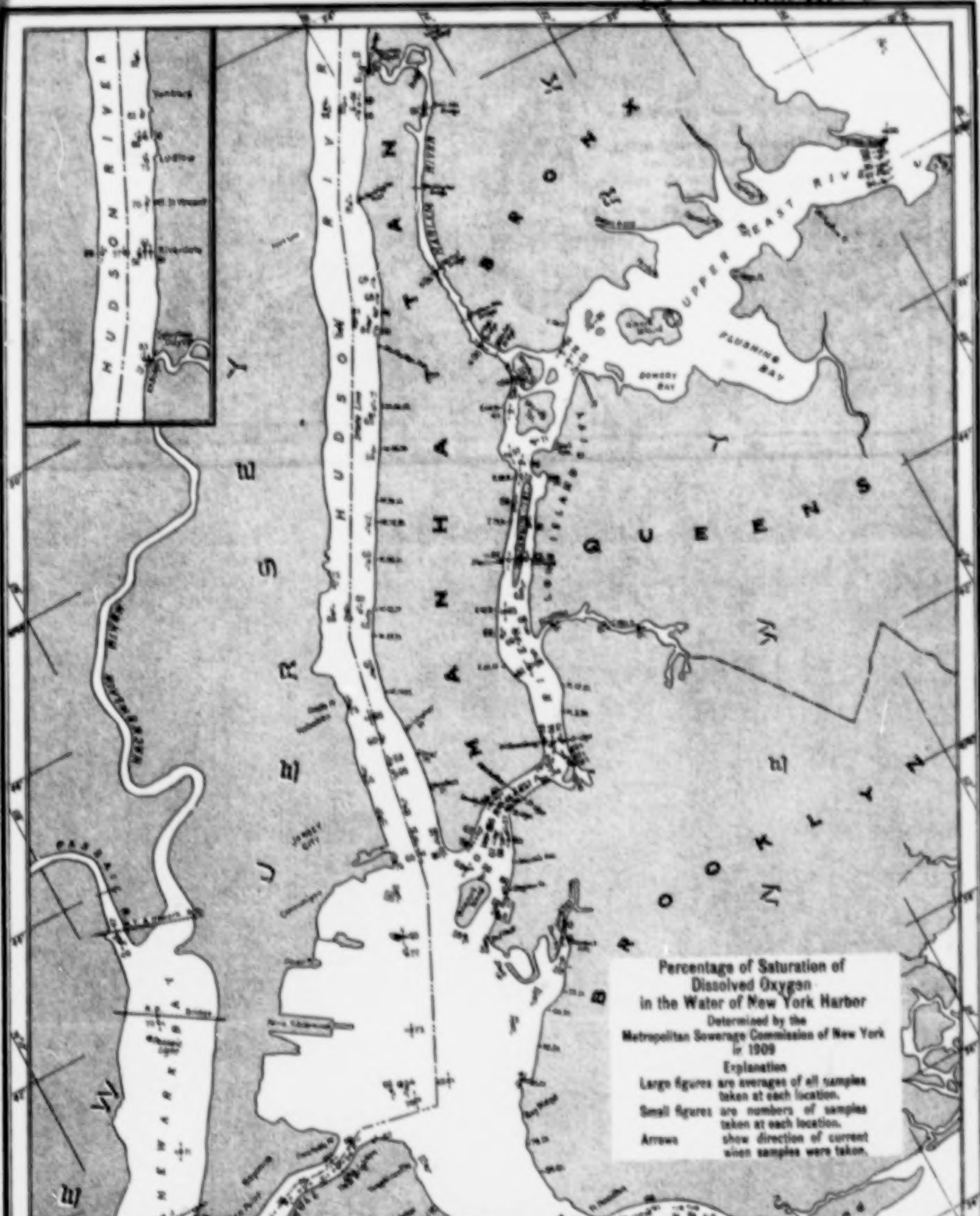
COMPLAINANTS' EXHIBITS Nos. 150, 151, 152, 153, 154, 155, and 156.

JAMES D. MAHER,
Commissioner.

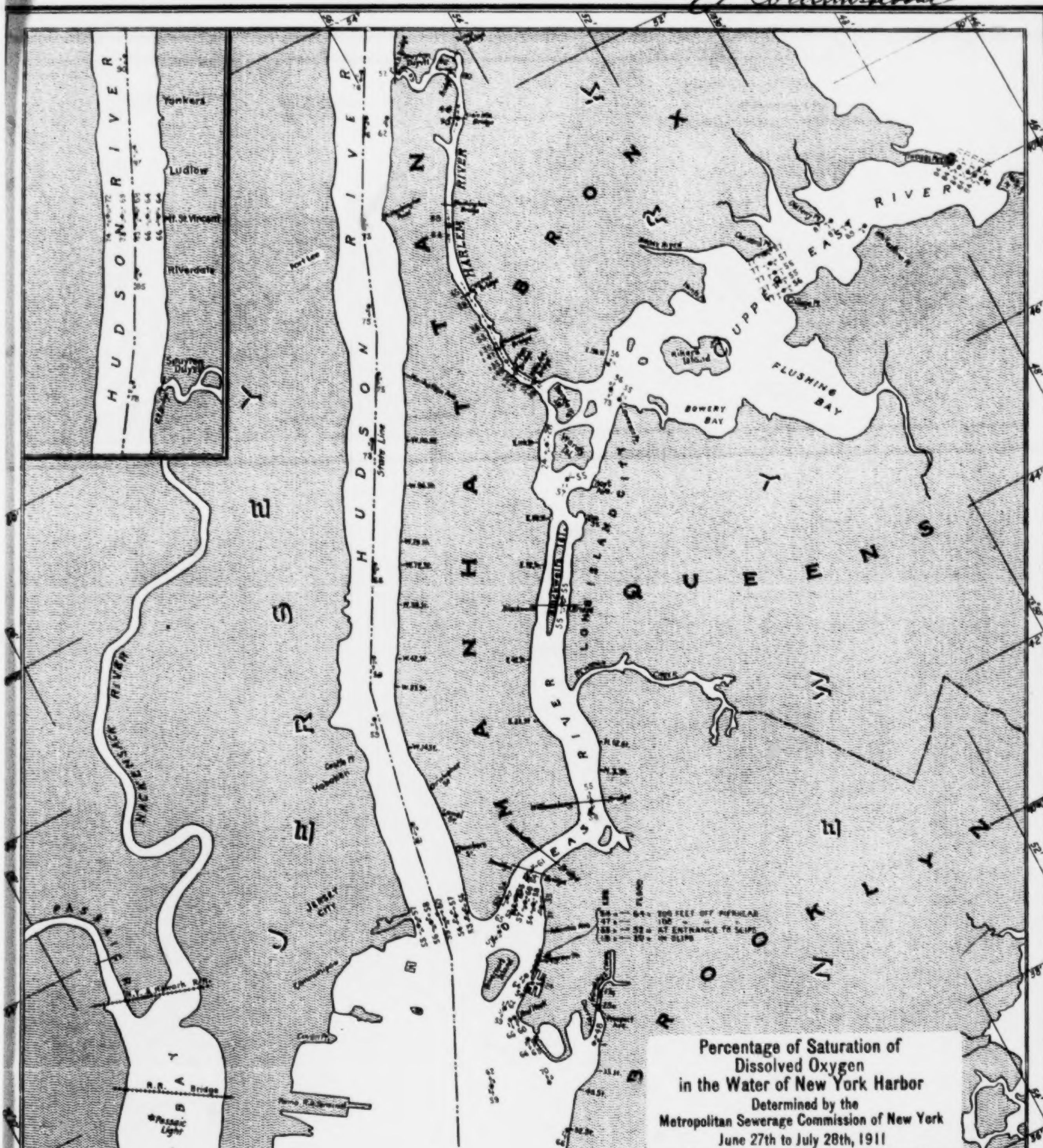
Complainants Exhibit No 150
James D. Maher
Commissioner



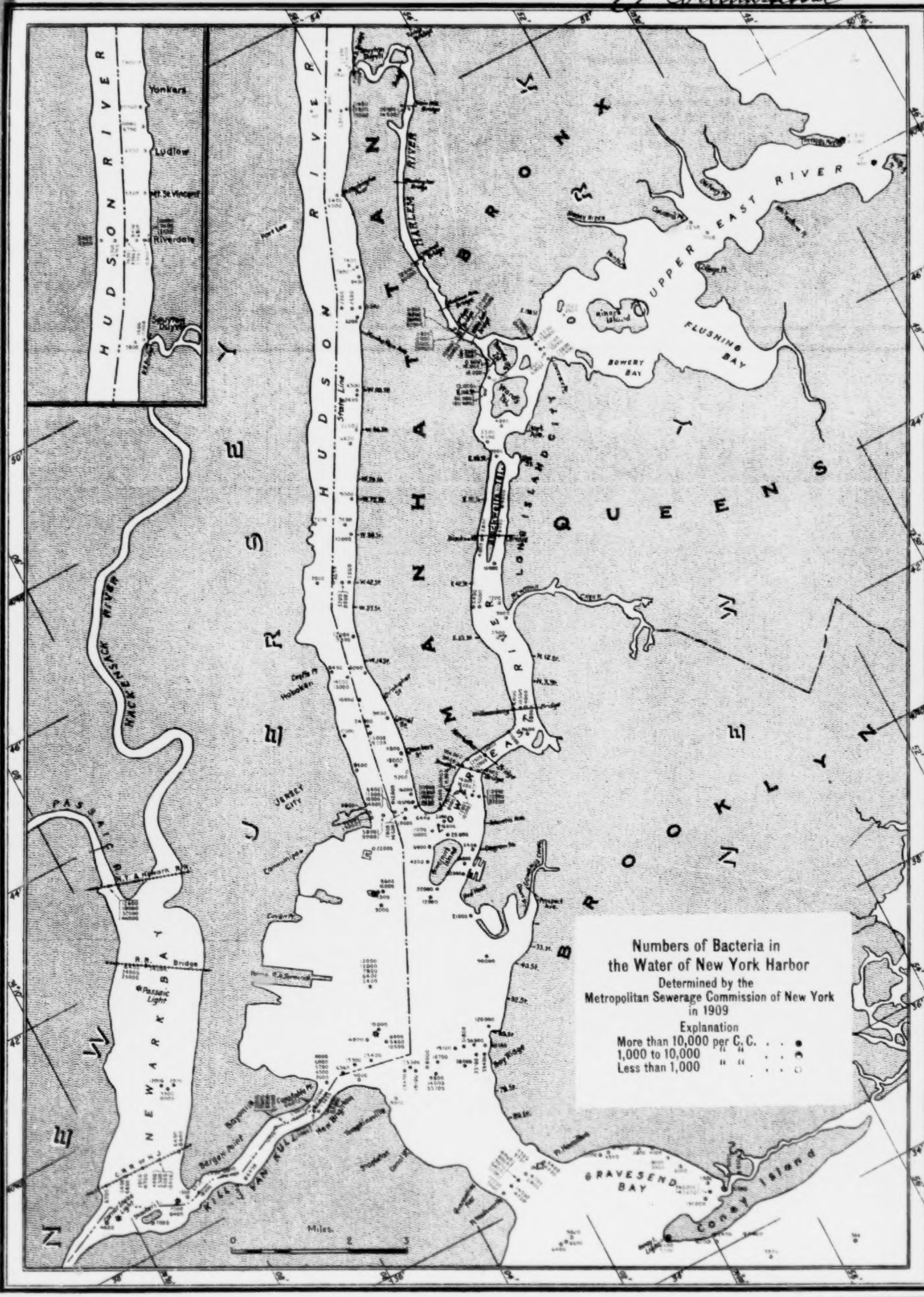
Complainants Exhibit No 151
James D. Maher
Commissioner



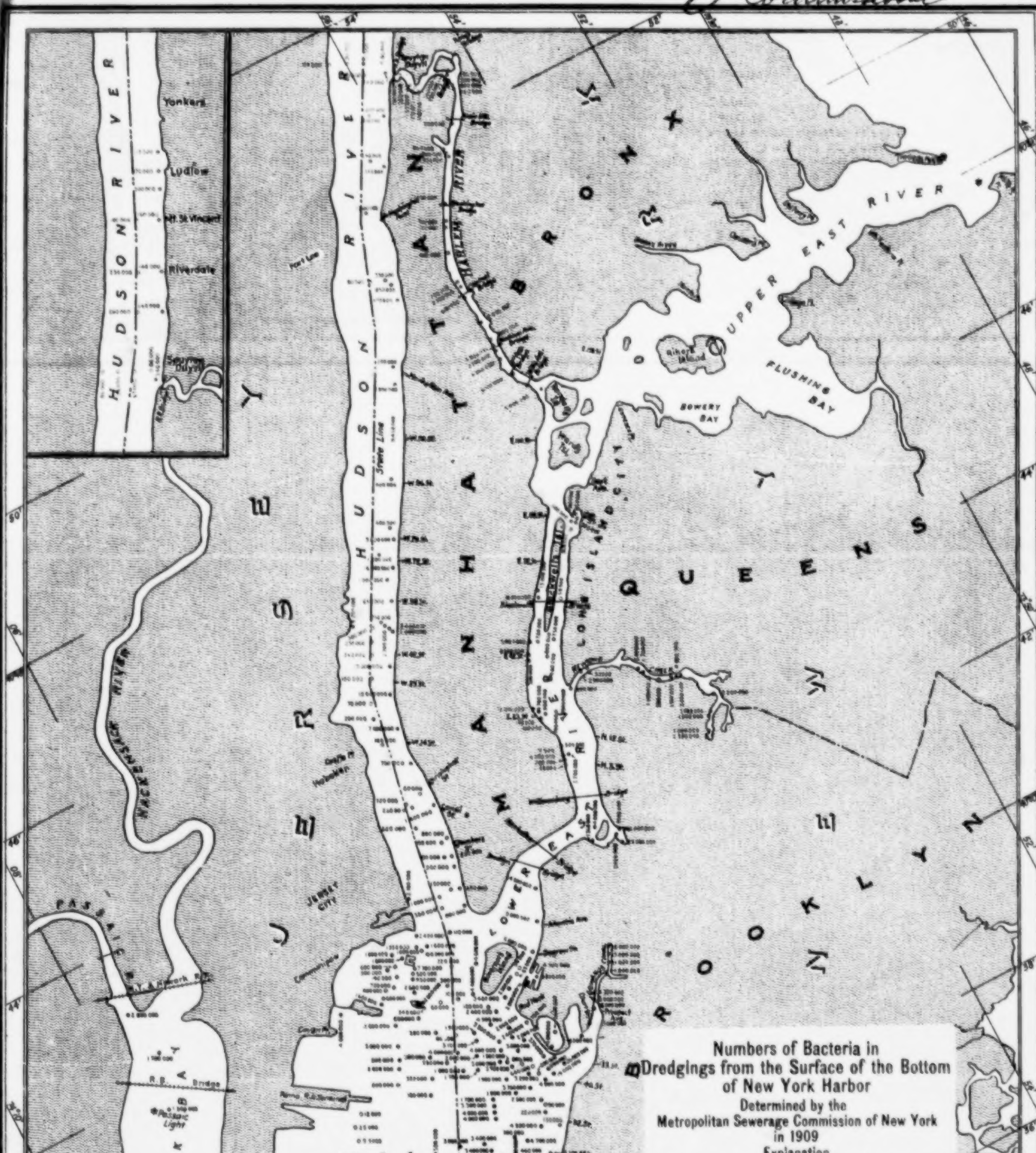
Complainants Exhibit No 152
James D Maher
Commissioner



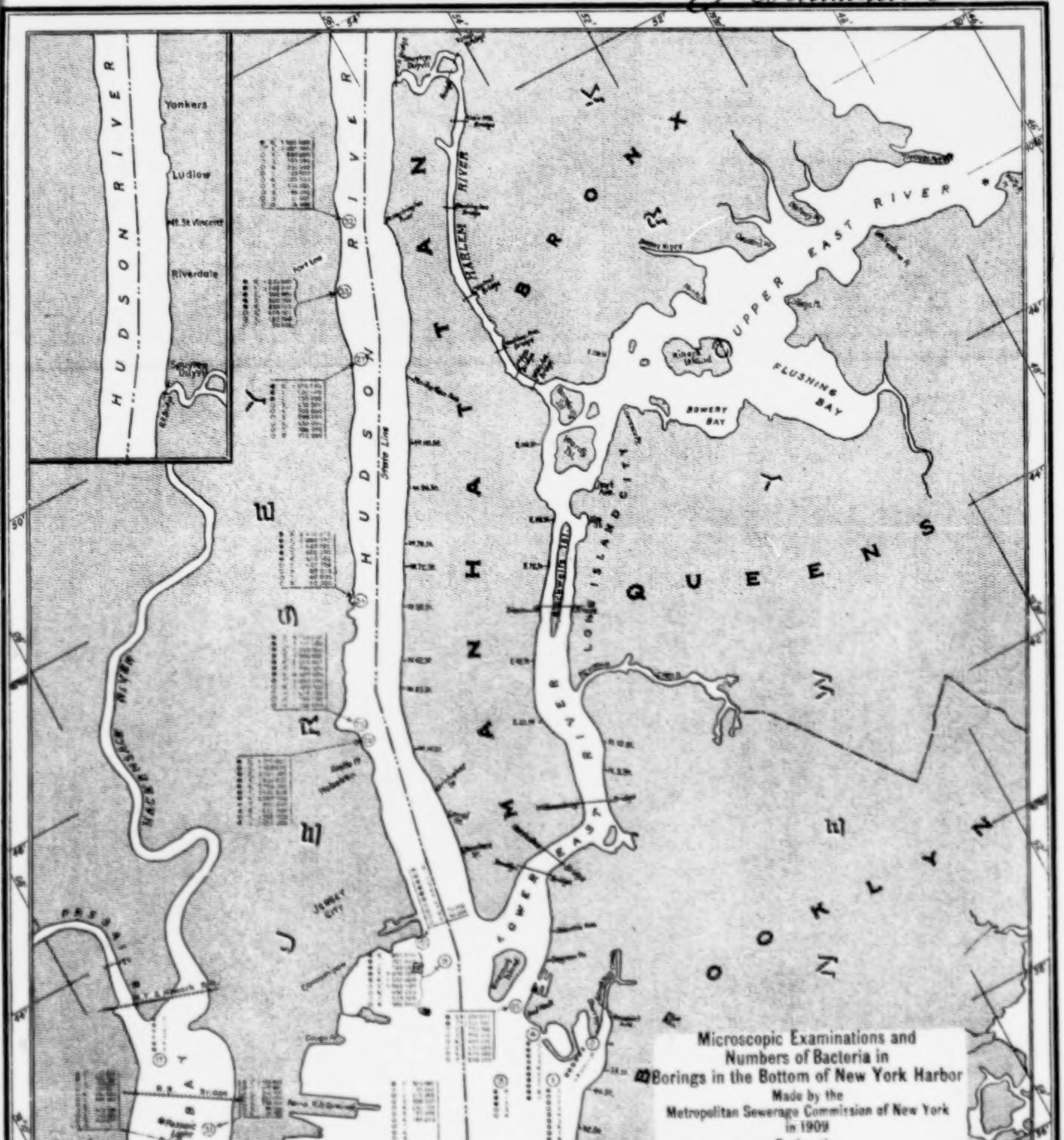
Complainants Exhibit No 153
James D Maher
Commissioner



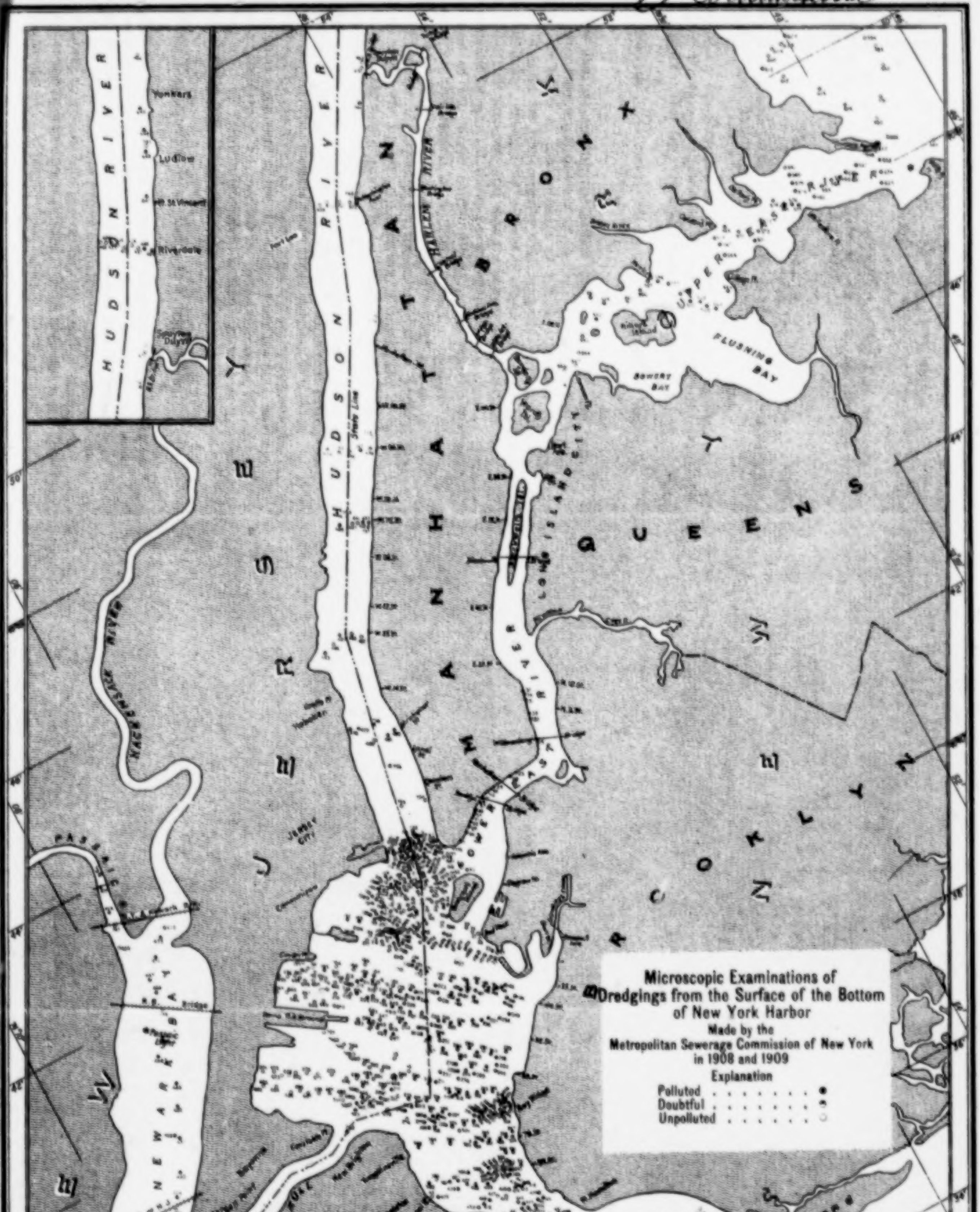
Complainants Exhibit No 154
James D Maher
Commissioner



Complainants Exhibit No 155
James D. Maher
Commissioner



Complainants Exhibit No 158
James D Maher
Commissioner



6 COMPLAINANT'S EXHIBIT No. 158. James D. Maher, Commissioner.

Report on the Estimate of the Central Committee that the Dry Weather Sewage Flow in the Metropolitan Sewerage District is Not Less than 125 Gals. Per Head Per Day.

February 6th, 1912.

John W. Alvord and Chas. B. Burdick, Hydraulic and Sanitary Engineers, Hartford Building Chicago.

1 *Report on the Estimate of the Central Committee that the Dry Weather Sewage Flow in the Metropolitan Sewerage District is Not Less than 125 Gals. Per Head Per Day.*

Volume of Sewage of Communities in the Metropolitan Sewerage District.

"Very few data concerning the actual discharge of sewage from the above named communities are available. Generally the water consumption is taken as the measure of the dry weather flow of sewage, but it must be remembered that appreciable quantities of water derived from independent sources of supply are used in most cities for industrial purposes, and that the sewers also receive a considerable amount of ground water by infiltration. In view of the fact that most of the larger communities in the District contain many industries, the central committee is of the opinion that a conservative estimate of dry weather flow of sewage is 125 gallons per head per day, on the average for the entire district, both at the present time and in the future. In arriving at this figure, it was assumed that measures would gradually be taken by most of the communities to check undue waste of water."

To satisfy myself that this estimate is conservative, I have made a careful study of the data which is available, and herein briefly review the conclusions which result from these studies, as follows:

As pointed out by the Central Committee, the water consumption is taken as a measure of the dry weather sewage flow, but that
2 this is considerably augmented by industrial waste, the water being supplied from independent sources, as well as infiltration of ground water into the sewer.

Water Consumption is an Index to Sewage Flow.

In the absence of continuous gaugings covering long periods of time, on sewered areas of known population, it becomes necessary to derive an estimate of the dry weather sewage flow by some other measure. It has often been the practice among engineers engaged in this line of work, to assume the per capita dry weather sewage flow equal to the per capita water consumption. This does not mean that

all the water supply is delivered to the sewer. There are a number of ways in which water may be used in such a way that it does not find its way to the sewer, among which are such uses of water as by steam railroads, some manufacturing and mechanical purposes, street and lawn sprinkling, etc.

At Milwaukee the Sewerage Commission in 1910 estimated the water which did not reach the sewer, as follows:

	Gallons per capita per day not reaching the sewer.
Steam railroads	5
Manufacturing and mechanical	5
Street sprinkling	5
Lawn sprinkling	2½
Consumers not connected to sewer	7½
Leakage from water mains & services	15
Total	40

3 This total of 40 gallons per capita represents about 35% of the total water supply. Probably considerable of the leakage from the mains and services finds its way to the sewer as ground water. The Commission assumed in making an estimate of the dry weather sewage flow that 35% of the water supply failed to reach the sewer.

Inasmuch as the water consumption is the principal factor determining the volume of the domestic sewage, I have prepared the following Table No. 1, giving the population and per capita water consumption of a number of cities. This table also gives the percentage of services that are metered, as this undoubtedly greatly influences the per capita consumption.

Table No. 2 gives the population of the various communities in the Metropolitan Sewerage District with the average water consumption at the present time in gallons per head per day for such communities where these data are available. The populations are as given in the 1910 U. S. Census.

From table No. 1 we find that in the seventy cities enumerated, the average consumption per capita daily to be 148 gallons. This average is determined by giving each city its relative weight in proportion to its population. This is done because in general the larger the city the larger the per capita consumption, and it is evi-
4 dent that the conditions in the larger cities are more nearly comparable with those in the Metropolitan District.

Considering Table No. 2, which is quite incomplete on account of the fact that the data pertaining to the water consumption in the various communities within the Metropolitan area is not available at this time, is probably the best index as to the average sewage flow to be expected from this area. From this table it appears that for the City of New York the average daily consumption of water per capita is 114 gallons. For the cities exclusive of the City of New

York, the average water consumption per capita is 111 gallons for the communities listed in Table No. 2, where the consumption is known. The total population of the communities in which the per capita water consumption is available, amounts to 5,998,342, of which, 4,937,243 reside in the City of New York. These data are therefore available for approximately 93.5% of the total population of the Metropolitan District which is 6,424,530, according to the U. S. Census for 1910.

Infiltration of Ground Water.

It is known that in a sewerage system, either sanitary or combined, the sewage flow is made up partially of ground water. This being caused by the ground water adjacent to the sewers, being at a higher level than the sewer, causing a seepage of this water
5 through the joints into the sewer. The amount of this leakage into the sewer is most largely dependent on the pervious or impervious character of the soil. Aside from this factor, the elevation of the ground water level with reference to the sewer, and the perviousness of the sewer itself, are of importance. It is possible to somewhat reduce the amount of ground water leakage by care in construction, but from an economical standpoint, it is usually undesirable to build sewers so that the infiltration of ground water is completely prevented, as in most cases the lowering of the ground water is a valuable and important function of the sewer.

Actual measurements of the ground water flow are too meager to be of general value, and it is evident in any event, that it would be impracticable to determine the part of ground water in the sewers of the Metropolitan area by actual gaugings. It has been suggested that minimum flow during the night is practically equal to the ground water infiltration. This is probably very nearly the case in residential districts, although even here the flow caused by leakage from house fixtures, etc., would vitiate the above assumption. In districts containing industries using water throughout the twenty-four hours, no dependence could be placed on this method of obtaining measurement of the ground water leakage.

The amount of ground water entering the sewer is obviously
6 independent of the population, and is usually expressed in gallons per acre per day, or gallons per mile of sewer per day. Expressing this flow in reference to miles of sewer is undoubtedly better than in reference to acreage, as the amount of seepage is undoubtedly proportional to the length of sewer laid, assuming that the local influencing condition is the same. To facilitate estimating the total flow in sewer districts, the unit gallons per head per day is usually used and for this reason it becomes necessary to express the ground water infiltration in this unit. It is possible to do this after the leakage per mile of sewer and the population on the area drained has been determined.

The Milwaukee Sewerage Commission recently had continuous gaugings covering a period of several days, made of a 72" sewer draining 358 acres of strictly residential portion of that city. Assuming the ground water infiltration equal to the minimum night

flow, it was found equivalent to 36,000 gallons per mile of sewer, 956 gallons per acre, or 31 gallons per capita. This sewer district is on comparatively high ground and the soil is of such a nature that the ground water infiltration is considerably less than in some of the lower portions of the city. The Commission came to the conclusion that the average leakage was 38 gallons per capita and the maximum rate was 76 gallons per capita.

7 From a study made of the data collected by the Engineers of the Metropolitan Sewerage Commission, Boston, relating to the flow in the North Metropolitan intercepting sewer, it is deduced that the ground water infiltration is equivalent to from 38.3 to 61.6 gallons per capita daily.

The following is a table showing the allowance made for ground water infiltration in various cities by engineers who have studied this matter.

Allowance Made for Ground-water Infiltration in Various Cities.

	Gals. per capita per day.			Gals. per acre per day.		
	Min.	Ave.	Max.	Min.	Ave.	Max.
Paterson, N. J. (Report of Joint Com. Sewage Disposal, '06, pp. 111)		14				
Louisville, H. P. Eddy		58				
Passaic Valley (Report Passaic Valley Sew. Com., 1908, p. 7)			29			
Milwaukee (Report Sewage Com., 1911)		38	76			
Neponset Intercepter, Boston (Report Met. Sew. Com., 1895, p. 38)			25			
High Level Sewer, Boston (Report Met. Sew. Com., 1899, p. 44)			24			
San Francisco (Grunsky's Report)	32*		97*	640		1,940
Indianapolis (Hering's Report, 1892)		25*			500	

* Computed from gals. per acre, assuming 20 people per acre.

8 From the table, and the observations cited hereinbefore, it is safe to assume that the ground water infiltration in a sewered area such as the Metropolitan Sewerage district, would average at least 25 gallons per capita per day.

Industrial Wastes.

No effort has been made to obtain complete information as to the quantity of industrial wastes discharged into sewers in the Metropolitan Sewerage District by industries obtaining their water from private sources. The only way to accurately determine the volume of industrial wastes in the Metropolitan area would be by a complete census of all the varied industries located within the district. This is probably at this time impracticable, and we must therefore, be satisfied with an estimate based on such data as *is* available.

In studying the question of industrial waste at Milwaukee, the Sewerage Commission adopted the allowance of 57 gallons per capita to cover a portion of the flow,—this amounting to 34.6% of the total sewage flow of 165 gallons per capita daily.

Sewage Flow Per Capita in Various Cities.

Records of gaugings of the dry weather flow in sewers are quite limited, especially gauges covering long periods of time. In table No. 3 I have tabulated such information on this subject
9 which I have collected from various sources. Possibly the best records of sewer gaugings covering a long period of time, are those made by the Metropolitan Sewerage Commission at Boston. These records are fully discussed in the appendix No. 1 attached hereto, taken from the report made by the Milwaukee Sewerage Commission in 1911. It would be of no significance to average the various quantities in this table as some of these are simply single guagings, while others covered periods of various lengths, including several estimates recommended to be used in several cities by engineers after making a study of this question.

It will be seen from the table that there is a great variation in the flow to be expected, and that this variation is considerably greater than the variation in the water consumption in various communities as shown in Table No. 2, which would tend to show that in determining the average sewage flow, other sources of sewage besides the public water consumption must be taken into consideration.

Report of Metropolitan Sewerage Commission of New York.

The Metropolitan Sewerage Commission of New York in their report of 1910 commented on the volume of sewage discharged into New York Harbor, as follows:

"The volume of sewage produced in any district depends primarily on the water consumption, including that obtained from wells or other private supplies. In some towns, such as Paterson, these private supplies furnishing artesian water for manufacturing purposes, such as dye works, silk mills, rolling mills, breweries, etc., constitute an important proportion of the total amount of water
10 used. If discharged into the sewers as is customary, it adds to the volume of the sewage, although it may not increase the total amount of the organic constituents of the sewage.

Aside from the water supply the flow of sewage may be materially increased by the infiltration of ground water through leaky sewers, or of surface waters through manhole covers. In the case of combined sewer the flow is enormously increased for short periods during storms.

On the other hand the volume of sewage carried by the sewers is diminshed, first, by the fact that suburban or rural areas are not provided with sewers, their liquid wastes going either to cesspools or on to the land; second, because in many instances manufacturing wastes are discharged directly to the nearest streams without passing through a sewer; third, by leakage from defective sewers into the soil, and fourth, on account of water used for street sprinkling and street cleaning purposes.

In a combination of towns such as is represented by those of the metropolitan district, it is believed a fair general estimate of the volume of sewage may be determined with the following assumptions:

1st. That the infiltration of surface and ground water to some sewers and the water used from private supplies will about offset that lost by leakage or by the ordinary direct disposal of streams and by street sprinkling.

2nd. That where an unusual discharge directly to streams is made from the mills, etc., due allowance to be made for this.

3rd. That the run-off directly due to storms be disregarded by assuming the dry-weather flow only of combined sewers.

4th. That districts without sewage facilities be omitted from consideration.

From these assumptions it follows that for the general purposes of this estimate the volume of sewage may be taken as equivalent to the water supply, corrected for any excessive discharge from other sources, or diversion to other outlets, by mills, etc.
11 In this way fluctuations due to non-resident population are accounted for without determining the number of people, the water supply being known."

Applying this method to the metropolitan district, this Commission prepared Table No. 4, setting forth the estimated sewage flow in 1910 and 1940. These estimates were made before U. S. Census — for 1910 were available and are therefore now subject to some correction, especially the forecast for 1940. Assuming the estimates for 1910 to be substantially correct, the total sewage flow for the Metropolitan district in 1910 amounts to 802 million gallons daily. The total population in 1910 according to the returns of the U. S. Census is 6,424,530, which amounts to a sewage flow of 125 gallons per head daily.

Conclusions.

That the estimate of an average sewage flow of 125 gallons per head per day for the Metropolitan district made by the Central Committee, both for the present time and in the future, is conservative, seems to be shown by practically all the data which I have collected on this subject. The estimate of the Metropolitan Sewerage Commission of New York shows present quantity amounting to 125 gallons per head daily and increasing considerably in the future.
12 The data relating to the water consumption amounting to 113 gallons per capita for 93.5% of the total population of the Metropolitan area would indicate that this will not be materially altered by the per capita consumption in the balance of the district. Assuming that 113 gallons represents the correct per capita water consumption daily and that due to reasons hereinbefore given, but 80% of this water actually reaches the sewers. This would amount to practically 90 gallons per capita. To this we must add an allowance for ground water infiltration which could be conservatively estimated at 25 gallons per capita. This would leave but 10 gallons per capita unaccounted for to take care of industrial waste, etc., the water being drawn from private sources.

The estimate of the Central Committee of 125 gallons of sewage per head per day is therefore conservative, and in my opinion, it is too low rather than too high.

13 TABLE No. 1.

Population & Water Consumption Per Capita Daily in Various Cities.

	Population. 1910.	Water consumption per capita daily.	Per cent metered.
1. Chicago	2,185,283	232	5.9%
2. Philadelphia	1,549,008	203	.6%
3. St. Louis	687,029	110	6.6%
4. Detroit	484,689	177	10.
5. Buffalo	423,715	314	4.3
6. Milwaukee	373,857	114	98
7. Washington, D. C.	331,069	75	29
8. Toronto, Ont.	395,000	89	4
9. Minneapolis	301,408	74	81
10. Jersey City, N. J.	267,779	150	8.7
11. Indianapolis	248,000	71	11.1
12. Kansas City	248,381	90	45.
13. Louisville, Ky.	223,928	99	8
14. St. Paul, Minn.	214,744	61	517
15. Portland, Ore.	207,214	83	30.1
16. Columbus	181,511	75.6	91.3
17. Toledo	168,497	93	80
18. Atlanta, Ga.	154,839	195	100
19. Worcester, Mass.	145,986	73	96
20. Schenectady, N. Y.	137,249	74	...
21. Memphis	131,105	103	45%
22. Richmond, Va.	127,628	96	68
23. Grand Rapids	112,571	142	42
24. Nashville, Tenn.	110,364	118	65
25. Cambridge, Mass.	104,839	99	30
26. Hartford, Conn.	103,329	75	100
27. Albany, N. Y.	100,253	223	23
28. New Bedford, Mass.	96,653	81	48
29. Pawtucket	96,191	66	86
30. Reading	96,071	129	15
31. Springfield, Mass.	88,926	119	61
32. Wilmington	87,400	118	34.3
33. Des Moines, Ia.	86,368	58.5	96
34. Lawrence, Mass.	85,892	45	91
35. Yonkers, N. Y.	79,803	103	100
36. Duluth	78,466	87.6	51.5
37. Houston, Texas	78,800	100	76
38. Manchester, N. H.	70,063	50	74
39. Erie, Pa.	66,525	207	2

14 TABLE No. 1—(Cont'd).

	Population. 1910.	Water consumption per capita daily.	Per cent metered.
40. Brockton, Mass.	64,170	39	100%
41. Holyoke, Mass.	57,730	102	9.
42. Jacksonville, Fla.	57,699	76.4	75%
43. South Bend, Ind.	53,884	88	18
44. Allentown, Pa.	51,913	138	.8
45. Springfield, Ill.	51,678	105	37.6
46. London, Ont.	50,000	116	7.4
47. Saginaw, Mich.	50,510	189	6
48. Binghamton, N. Y.	48,443	139.5	30
49. Rockford, Ill.	45,501	79	43
50. Haverhill, Mass.	44,115	72	17
51. Lincoln, Neb.	43,973	60	...
52. Davenport, Ia.	43,028	95	57
53. Macon, Ga.	40,662	100	26
54. Newtown, Mass.	39,806	65	89
55. Dubuque, Ia.	39,494	65	...
56. Kalamazoo, Mich.	39,437	49	100
57. Flint, Mich.	38,560	126	26
58. Quincy, Ill.	36,587	55	60
59. Lexington, Ky.	35,090	54	99
60. Auburn, N. Y.	34,668	179	10
61. Aurora, Ill.	29,807	67	86
62. East Orange, N. J.	29,630	100	10
63. Poughkeepsie, N. Y.	27,936	83.2	98
64. Waltham	27,834	88	.12
65. Lewistown, Me.	26,247	158	8
66. Madison	25,531	93	100
67. Cumberland, Md.	21,839	264	...
68. Port Huron, Mich.	18,863	375	7
69. Streator	14,253	139	9.1
70. Holland, Mich.	10,497	80	100

Weighted Average (pumpage per capita $= \frac{1,765,600,000}{11,926,400} =$) 148.0 gals. per capita daily.

15 TABLE No. 2.

Population & Per Capita Water Consumption for Various Communities.

Metropolitan Sewerage District.

State of New York:

	U. S. Census, 1910.	Water consumption, gals. per capita daily.
Manhattan	2,331,542	131
The Bronx	430,980	93
Brooklyn	1,634,351	98
Queens	284,041	102
Richmond	85,969	93
City of New York (Total)	4,766,883	114
Westchester and Nassau Counties:		
Yonkers	79,803	103
White Plains	15,045	
Scarsdale	1,300	
Tuckahoe	2,722	
Bronxville	1,863	
Mt. Vernon	30,919	100
New Rochelle	28,867	
Pelham	2,998	
Great Neck Landing & part of Great Neck	1,783	
Not included in above	5,060	
	170,360	
Total in State of New York	4,937,243	
State of New Jersey:		
Bergen County:		
Outside of Passaic Valley:		
Fairview	2,441	
Ridgefield	986	
Cliffside Park	3,394	
Palisade Park	1,411	
Leonia	1,486	

16 TABLE No. 2.—(Cont'd).

State of New Jersey (Cont'd):
Bergen County (Cont'd):
Outside of Passaic Valley (Cont'd):

	U. S. Census, 1910.	Water consumption, gals. per capita daily.
Englewood	9,924	
Teaneck	2,082	
Bogota	1,125	
Overpeck	4,512	
New Barbadoes	14,050	
Maywood	889	
Lodi Township	693	
Hasbrouck Heights	849	
Little Ferry	2,541	
Woodridge	681	
Carlstadt	1,964	
E. Rutherford	2,249	
Rutherford	3,663	
Union Twp.	2,038	
North Arlington	218	
Edgewater, Fort Lee and Englewood Cliffs	5,879	
Total outside Passaic Valley	63,055	
Inside of Passaic Valley:		
Glen Rock	1,055	
Saddle River	3,047	
Midland	303	
Garfield	10,213	
Lodi Borough	4,138	
Hasbrouck Heights	1,306	
Woodridge	362	
Wallington	3,448	
Carlstadt	1,843	
East Rutherford	2,026	
Rutherford	3,382	
Union	2,038	
North Arlington	219	
Total inside Passaic Valley	33,380	

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TABLE No. 2—(Cont'd).

State of New Jersey (Cont'd):
Essex County:
Outside of Passaic Valley:

	U. S. Census, 1910.	Water consumption, gals. per capita daily.
Irvington	11,877	
South Orange	6,014	
West Orange	10,980	
South Orange	2,979	
Not included in above	5,477	
Total outside Passaic Valley	37,327	
Inside of Passaic Valley:		
Newark City (99%)	343,994	98
Orange "	29,630	
E. Orange	34,371	
Bloomfield	15,070	
Belleville	9,891	
Montclair	21,550	
Nutley & Glen Ridge	9,269	
Total inside Passaic Valley	463,775	
Hudson County:		
Outside of Passaic Valley:		
Bayonne	55,545	
Jersey City	267,779	150
Hoboken	70,324	114
West Hoboken	35,403	
Union	21,023	
West New York	13,560	
Weehawken	11,228	
North Bergen	15,662	
Not included in above	10,387	
Total outside Passaic Valley	500,911	
Inside of Passaic Valley:		
Harrison	14,498	124
East Newark	3,163	
Kearney	18,659	102
Total inside Passaic Valley	36,320	

18 TABLE No. 2—(Cont'd).

State of New Jersey (Cont'd):
Passaic County:
Inside of Passaic Valley:

	U. S. Census, 1910.	Water consumption, gals. per capita daily.
Patterson City	125,600	80
Passaic "	54,773	79
Acquackononk	11,869	
Manchester, Prospect Park and Hawthorne	8,679	
Total inside Passaic Valley	200,921	
Middlesex County: Outside of Passaic Valley:		
Roosevelt	5,786	
Woodbridge	8,948	
Perth Amboy	32,121	
Total	43,171*	
Union County: Outside of Passaic Valley:		
Elizabeth	73,409	82
Roselle Park	3,138	
Millburn	3,720	
Summit	7,500	
Union Township	3,419	
Rahway	9,337	
Cranford	3,641	
Garwood	1,118	
Not included in above	3,145	
Total outside Passaic Valley	108,427	
Total in State of New Jersey:		
Inside of Passaic Valley	734,396	
Outside of Passaic Valley	752,891	
Total	1,487,287	
Total in Metropolitan District	6,424,530	

(* Adds to 46,855 see page 6a and 11 of Basic Physical Data.)

TABLE NO. 3.

Gaugings of Dry Weather Flow of Sewers.

	Location.	Population. Date.	Total.	Tritbutary.	Sewage Flow. Min.	Ave.	Max.
1.	Compton Ave., St. Louis..................	1880	8,200	.....	65	102	140
2.	College St., Burlington, Vt................	1880	.....	325	65	115	140
3.	Huron St., Milwaukee, Wis.................	1890	4,036	3,175	..	...	120
4.	Memphis, Tenn.	1881	3,500	20,000	61	...	140
5.	13 Sewers, Providence, R. I................	1884	.....	33,825	..	78	...
6.	16 " Toronto, Can.	1891	.....	168,081	..	87	...
7.	Des Moines, Ia., E. Side..................	1895	13,100	3,100	22.5	74	142
8.	" " " W. "	1895	28,000	19,400	23.2	66	175.3
9.	Schenectady, N. Y..........................	1892	.....	10,000	72	86	103.0
10.	Canton, O.	1893	.....	40,000	54	129	180.0
11.	Chautauqua	1894	.....	7,000	6	20	30.0
12.	Chicago:						
	Diversey Blvd. (W)......................	1911	23,550	.....	..	238	...
	Randolph St. (W).......................	1911	11,368	.....	..	348	...
	Robey St. (S)............................	1911	38,728	.....	..	169	...
	Ashland Ave. (S).......................	1911	44,581	.....	..	338	...
	Center Ave. (S).........................	1911	23,463	.....	..	578	...
	39th St. Pumping Station...............	1909	285,900	.....	..	*318	...
	" " " "	1909	285,900	.....	..	**227	...
	92nd St. Sewer...........................	....	3,606	.....	..	325	...
	Wentworth Ave. (S) Calumet...........	....	30,464	.....	..	264	...
13.	North Metropolitan Sewer District.........	1904–'09	490,000	.....	..	120	...
14.	San Francisco (Estimated in Grunsky Report) (without ground water)............	....	.....	.....	..	70	...
15.	Indianapolis (Rudolph Hering Report, 1892 (Est.)	....	.....	.....	..	90	...
16.	Worcester	1904	132,000	.....	..	118	...

13—Ex. 158

TABLE No. 3.—(Continued).

Gaugings of Dry Weather Flow of Sewers.

	Location.	Population.			Sewage Flow.		
		Date.	Total.	Tritibutary.	Min.	Avr.	Max.
17.	London—Report of Maurice Fitzmorris.....	1901	5,136,000	.....	..	55	...
18.	Milwaukee, Gaugings, Oct. 24-28—72" sewer.	1910	11,000	.....	31	83.5	207
19.	Milwaukee Est. of Sewage Commission.....	1911	373,857	.....	..	165	...
20.	Calumet District, Chicago (Est. Hering & Fuller)	1908	.....	.....	..	130	...

References:
1-7. Eng. News, pp. 132, Vol. XXXV; also Ogden sewer design.
9-10-11. Ogden sewer design, pp. 113.
12. G. M. Wisner.—Report on Sewage Disposal—San. Dis. Chicago—Oct. 12, 1911.
16. Eng. Record—Apr. 23, 1904—pp. 529.

* This run-off or more 76 days in 1909.
** This run-off or more 276 days in 1909.

20 **Table No. 4.**

Volumes of Sewage Produced in the Metropolitan District.

New York State:

	Million gallons per day. 1910.	1940.
Manhattan	343	650
The Bronx	45	195
Brooklyn	160	560
Queens	27	145
Richmond	8	30
The City of New York	583[1]	1,580.0
Mt. Vernon	3[3]	9.7
New Rochelle	1[3]	3.2
Yonkers	9[4]	27.4
Bronx Valley	3[5]	9.1
	599	1,629.4
New Jersey, Bergen County:		
New Barbadoes (Hackensack)	1.0[1]	1.4[1]
Passaic Valley sewer district	5.7[6]	41.3[6]
Balance of Bergen County in metropolitan district	...	3.7[1]
Union County:		
Elizabeth	6.0[4]	21.8[1]
Rahway	1.0[1]	.8[1]
Westfield and Cranford	1.0[1]	2.0[1]
Joint outlet sewer	8.0[7]	13.9[6]
Essex County, Passaic Valley sewer district:		
Newark	52.0[4]	93.7[1]
Orange	4.5[1]	10.8[1]
East Orange	4.1[1]	12.1[1]
Balance of Passaic valley district in Essex County	14.7[1]	42.4[1]

[1] Based on the consumption of water. [2] Eng. News, Apr. 29, 1909. [3] N. Y. State Bd. Hlth., 1907. [4] U. S. Census Bul., 105, 1907. [5] Letter G. R. Byrne, Ch. Engr., May 5, 1909. [6] Rep. Passaic Valley Sewerage Com., 1908. [7] Letter from Alexander Potter, Nov. 16, 1908.

21

Table No. 4. (Cont'd).

Volumes of Sewage Produced in the Metropolitan District.

	Million gallons per day.	
New Jersey, Hudson County:		
Jersey City	39[2]	54.4[3]
Hoboken	8[2]	12.9[3]
Bayonne	4.3[2]	22.0[3]
West Hoboken	1[2]	13.4[3]
Union	2[2]	5.1[3]
North Bergen	1.5[2]	3.1[3]
Weehawken	1[2]	5.7[3]
West New York	1[2]	3.4[3]
Passaic valley sewer district:		
Kearney	1.9[1]	12.9[3]
Harrison	1.8[1]	8.2[3]
East Newark	.6[1]	1.2[3]
Miscellaneous	....	3.9[3]
Middlesex County:		
Perth Amboy	3.5[2]	14.0[3]
Woodbridge	....	1.7[3]
Passaic County, Passaic valley sewer district:		
Paterson	31[2]	64.8[1]
Passaic	4[2]	28.1[1]
Balance of Passaic valley sewer district in Passaic County	4.4[1]	17.1[1]
	203	515.2
Total for Metropolitan District	802.0*	2,144.6

[1] Rep. Passaic Valley Sewerage Com., 1908.
[2] Based on the consumption of water.
[3] U. S. Census Bul., 105, 1907.
*Total in original report was 741.—was probably a typographical error.

22 APPENDIX No. 1.

Extracts from Report of the Milwaukee Sewage Commission on the Quantity of Sewage Likely to be Produced.

April 25th, 1911.

By John W. Alvord, Geo. C. Whipple, Harrison P. Eddy, Commission.

23 Recommendation of Commission as to Quantity of Sewage to be Provided for: The average volume of sewage at the present time is estimated to be 61,000,000 gallons per day. Guided by the estimated future population and area, and a study of the water consumption and its probable increase, the amount of water likely to be used for manufacturing, and the amount of ground water leaking into the sewers, we have estimated that in 1930 the average daily volume of sewage for a considerable period of time each year, will be about 100,000,000 gallons, and in 1950, 155,000,000 gallons. The maximum rate of flow of sewage is now estimated to be about 107 million gallons daily, in 1930, 176 million gallons, and 265,000,000 gallons in 1950. The latter is equal 312 gallons per capita.

Data upon which Above Recommendation Was Made.

Actual Quantity of Water Supply Reaching Sewers.

As shown in detail in the consideration of the flow of sewage in the North Metropolitan intercepter in Boston, the quantity of sewage flowing in dry weather is frequently equivalent to not over ninety per cent of the water consumption. It cannot be reasoned from this fact however, that ninety per cent of the water supply is delivered to the sewer.

24 There are many ways in which water is used or lost without finding its way to the sewers. Among these may be mentioned railroad uses, water used for steam purposes, street and lawn sprinkling, that supplied to buildings not connected with sewers, and, probably the largest item of all, leakage from the water mains and services. The losses from these sources may be estimated as follows, based upon an assumed supply in Milwaukee in 1910 of 105 gallons per capita per day:

Table 18.

Estimated Quantities of Water Furnished by Water Works which do Not Reach the Sewers.

Milwaukee, 1910.

	Gals. per capita per day.
Steam railroads	5
Manufacturing and Mechanical purposes	5
Street Sprinkling	5
Lawn Sprinkling	2½
Consumers not connected with sewers	7½
Leakage from mains and services	15
Total	40

The total of these losses (40 gallons per capita per day) is equivalent to slightly over 38% of the supply. This estimate is based upon fragmentary and, in some cases, unsatisfactory information, but it seems reasonable to assume that at least 35% of the water supply will fail to reach the sewers by way of the house drains.

It should be mentioned in passing, that the leakage from the water mains and services tends to increase the supply of ground water, and that doubtless much of this water may eventually find its way into the sewers in the form of leakage.

The quantity of the municipal water supply estimated to reach the sewers, is therefore in round numbers as follows:

Table 19.

Estimated Quantity of Municipal Water Supply which Will Reach the Sewers.

1910	70	gals. per capita per day.
1920	72½	" " " "
1930	75	" " " "
1940	80	" " " "
1950	85	" " " "

Ground Water.

As indicated by the name, this classification includes such waters as find their way by means of leakage from the ground into the sewers. It is also intended to include such surface water as leaks through perforated manhole covers and defective brickwork in manholes, and the surface water which flows during comparatively dry weather and after the run-off ordinarily considered as storm water has ceased to flow, in small natural brooks necessarily connected with a sewer system built upon the combined plan.

While a large proportion,—probably in Milwaukee from 50 to 75

per cent.—of the rainfall runs off into the sewers very quickly after it has fallen, and is therefore properly called storm water, the remainder slowly percolates into the ground and supplies the natural underground streams, and is here referred to as ground water.

Sewers are often necessarily built at such a depth as to lie
26 below the natural surface of such waters, and if they are not
perfectly tight,—condition almost impossible to obtain,—there is more or less leakage into the pipes, with a consequent lowering of the ground water level.

Another source of ground water is the filtration from the rivers into the land lying near them. It is quite possible, in a city located like Milwaukee, that more or less of such water will find its way into the sewers lying comparatively near to the rivers.

The natural ground water (not the water filtering from the rivers) varies in elevation from season to season. During the spring when the frost is coming out of the ground and leaving the soil porous, so that the rain and melting snow can penetrate it easily, the supply of ground water is greatly increased, and the elevation of the water table usually rises several feet. As this water flows away through natural channels, or finds its way by infiltration into the sewer system, the elevation of the ground water is gradually reduced, and as this reduction takes place, there is less head upon the sewers and the quantity of infiltration becomes gradually less and less, until if the supply is not replenished, the quantity of leakage from this source may be reduced to nil. It is also true that the elevation of ground water varies from year to year with the quantity and distribution of rainfall.

27 The sewers first built in a district usually follow in a general way the natural water courses, and therefore lie in the bottoms of the valleys. Such sewers are often, especially in case of combined systems, built very close to, or actually in the natural beds of brooks. They are not usually extended to the extreme upper end of the district at first, and consequently the natural run-off through these brooks is taken into the sewers. Such brooks frequently flow, with gradually diminishing volume, for many days after the immediate run-off from a storm has passed by, and perhaps even throughout the dry season. The flow during the remainder of the time, until the next storm, is made up of the water draining out of the land, and is therefore logically classed with ground water, and, as its flow is continuous though gradually diminishing, it has the same effect upon the quantity of sewage. As a result of these conditions, such sewers receive comparatively large quantities of ground water, while it is but natural to expect that sewers built in these districts in later years, necessarily at higher elevations, will receive smaller quantities of leakage and brook flow.

Many measurements have been made to determine the quantity of ground water which finds its way into sewer systems. The results of these observations, indicate that the quantity of infiltration may be as low, under the most favorable conditions, as 5,000 or
28 10,000 gallons per day per mile of sewer. On the other hand, they show that the leakage frequently amounts to from 20,000

to 40,000 gallons per day, and at times of very high ground water, or during rain when there is leakage through manhole covers, even in separate systems it may run as high as 100,000 gallons per day per mile of sewer. In fact, there are instances where the leakage has materially exceeded this quantity.

As a rule, there has been a growing tendency toward securing as nearly water-tight construction as possible, so that it is undoubtedly true that the older systems receive greater quantities of ground water than some of the better constructed modern systems.

A Study of Records of Quantity of Sewage Delivered by the North Metropolitan Sewer, Boston, Mass.

Obviously, it has been impossible for us to obtain complete data regar-ing the quantity of sewage produced at Milwaukee, with observations of the rate of flow at different hours of the day, days of the week and seasons of the year. Such information can be collected only by continuous records extending over several years, and it is practicable to collect it only when the sewage is delivered to a single point instead of being discharged at many different points, as at Milwaukee. For this reason it has been deemed wise to make a study of such records collected in other places, and to apply
29 the lessons drawn from them to conditions at Milwaukee, giving proper weight to differences in local conditions.

The best data relating to the flow of sewage, available for study, appear to be those collected by the Engineers of the Metropolitan Sewerage Commission, Boston, Mass., who have practically continuous records extending back over many years. Our study has been confined, for the most part, to data relating to the North Metropolitan intercepting sewer. The district served includes 15 cities and towns, many of which are provided with the separate system of sewers. The cities of Cambridge, Everett, Chelsea and Somerville, and the Charlestown and East Boston districts in the City of Boston, which are served by this intercepter, are sewered upon the combined plan, and automatic regulators are provided at the sewer intersections, so that when the intercepting sewer is full, the gates are partially or wholly closed, and the surplus flow in the trunk sewers is discharged directly into the water courses or the harbor.

This sewer was designed to serve a territory of 46,000 acres, and a population of 571,000 in 1930. In 1909, the area served was 18,560 acres and the population 511,500.

Table 20 is a compilation of certain data based upon the entire population of the district tributary to this sewer, for the years 1904 to 1909 inclusive. The average quantities of sewage per day, per acre and per capita, (columns 3 and 4) are doubtless some-
30 what greater than if the storm water from the districts sewered on the combined plan was not received; but as those quantities represent the monthly averages, the error is probably not serious. On the other hand, there are overflows from the intercepter, which reli-ve it at times of excessive flow. Column 5 purports to be the maximum quantity per capita for a single day, but is obviously

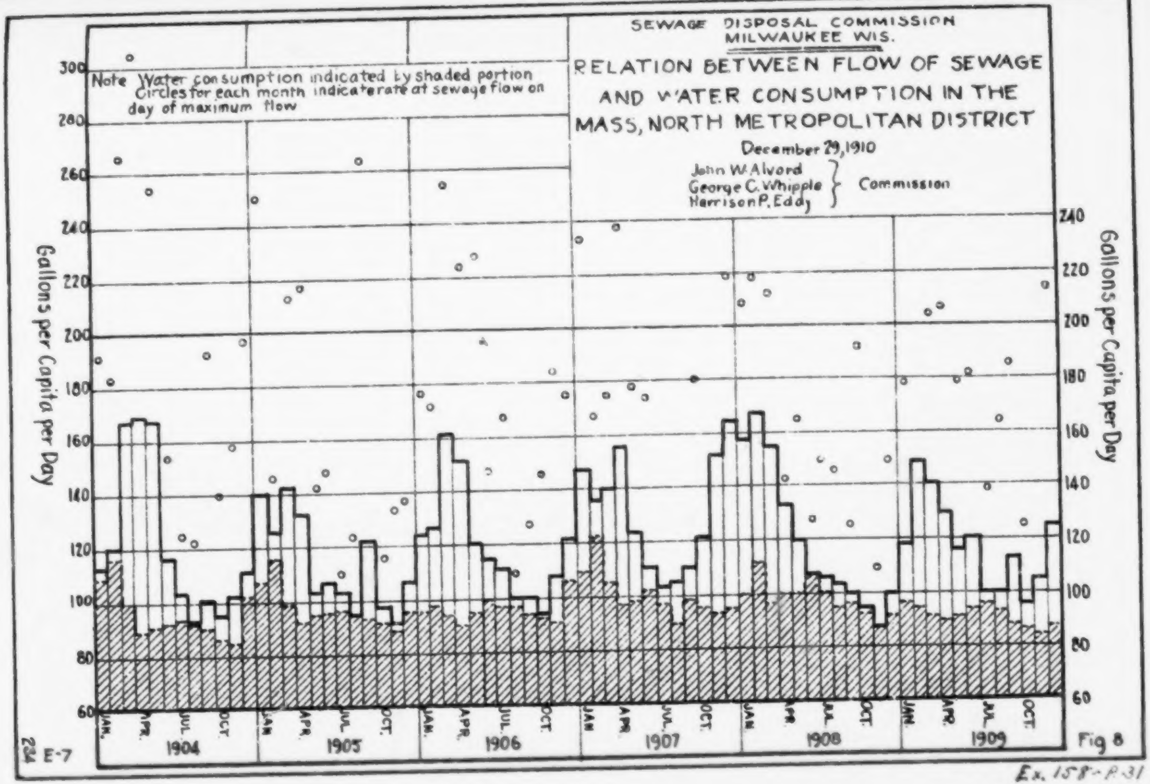

Fig 8

Ex. 158-P.31

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considerably lower than the actual quantity, if the sewer were ample to provide for the district as originally planned. On account of the tributary combined systems, these quantities are all more or less affected by storm water, although it is apparent that but little can be accommodated.

The yearly averages of the quantity of sewage and of the water consumption are given in Table 21, which also shows the relation between the average quantity of sewage and the average water consumption. Column 5 is made up of the percentage which the quantity of sewage is of the water consumption. It will be noted that this percentage varies from 115.7 to 128.7. It would seem to be a reasonably fair assumption for this district that the sewage flow would on an average be about 25% in excess of the quantity of water consumed.

(Here follows diagram, Fig. 8, marked page 31, Complainants' Exhibit 158.)

Fig. 8 shows graphically the relation between the average quantity of sewage and water consumption, as well as the maximum quantity of sewage for a single day. The shaded portion shows the quantity of water consumed. The shaded portion plus the unshaded portion below the heavy line, represents the quantity of sewage. The
32 small circles show the maximum quantity of sewage for a single day in each month.

33 TABLE 20.

Quantity of Sewage Dischaged from North Metropolitan Sewer District, Boston, Mass.

(Calculations based on entire population of tributary district.)

Date.	Population.	Ave. quantity per acre per day.	Ave. quantity per capita per day.	Max. quantity per capita upon one day.	Min. quantity per capita upon one day.	Ave. water consumption per capita per day.
(1)	(2)	(3)	(4)	(5)	(6)	(7)
		Gallons.	Gallons.	Gallons.	Gallons.	Gallons.
1904.						
Jan.	470,635	3030	109.9	192.0	86.3	113.2
Feb.		3291	119.4	185.5	98.2	117.1
Mar.		4650	168.7	265.0	130.0	99.6
Apr.		4700	170.5	308.0	111.8	88.0
May		4645	168.5	253.0	128.8	91.0
June		3175	115.2	153.9	91.6	91.9
July		2825	102.4	123.5	86.7	94.2
Aug.		2575	93.5	122.8	77.8	91.9
Sept.		2781	100.9	190.9	79.2	91.2
Oct.		2630	95.4	138.7	79.3	86.7
Nov.		2830	102.6	158.5	90.5	85.7
Dec.		3045	110.5	197.0	95.4	102.0
1905.						
Jan.	478,800	3911	140.6	248.5	110.5	106.3
Feb.		3505	126.0	144.8	106.5	117.0
Mar.		3990	143.1	213.0	99.9	99.2
Apr.		3715	133.5	217.5	100.9	92.0
May		2875	103.3	141.3	91.5	96.1
June		2991	107.5	148.4	75.6	96.6
July		2700	97.0	111.1	86.9	102.7
Aug.		2620	94.0	122.5	79.0	94.6
Sept.		3421	123.0	264.5	94.9	94.1
Oct.		2705	97.1	115.7	82.1	92.2
Nov.		2561	91.9	134.1	71.3	80.7
Dec.		2975	107.0	136.9	88.4	96.2
1906.						
Jan.	486,965	3430	123.7	178.0	99.2	96.2
Feb.		3550	128.0	173.0	101.5	99.4
Mar.		4540	163.7	255.0	130.6	95.0
Apr.		4220	152.0	223.5	110.0	91.8
May		3315	119.6	229.0	93.3	96.4
June		3175	114.5	148.0	98.6	99.6
July		3090	111.5	168.3	87.9	97.7
Aug.		2684	98.8	110.4	81.8	100.0

Date.	Population.	Ave. quantity per acre per day.	Ave. quantity per capita per day.	Max. quantity per capita upon one day.	Min. quantity per capita upon one day.	Ave. water consumption per capita per day.
(1)	(2)	(3)	(4)	(5)	(6)	(7)
		Gallons.	Gallons.	Gallons.	Gallons.	Gallons.
Sept.	....	2655	95.8	127.8	85.9	100.3
Oct.	....	2655	95.8	146.4	80.7	93.6
Nov.	....	2966	108.1	184.2	86.9	91.7
Dec.	....	3415	123.0	175.0	94.3	107.0
1907.						
Jan.	 495,150	4055	148.3	232.0	122.8	111.6
Feb.	....	3765	137.7	168.0	115.1	123.0
Mar.	....	3855	141.0	174.8	115.7	106.0
Apr.	....	4285	156.7	237.5	120.2	97.8
May	....	3390	123.6	178.2	110.3	98.0
June	....	3020	110.5	174.8	86.0	102.0
July	....	2640	96.6	115.9	86.0	104.5
Aug.	....	2450	89.7	98.6	80.0	106.0
Sept.	....	3065	112.0	257.0	77.3	98.5
Oct.	....	3350	122.5	179.8	95.9	96.0
Nov.	....	4195	153.5	205.0	104.3	94.0
Dec.	....	4515	165.2	219.0	134.7	95.4
1908.						
Jan.	 503,330	4345	158.2	208.5	117.0	101.0
Feb.	....	4650	169.3	218.0	129.8	113.0
Mar.	....	4235	154.3	213.0	127.5	97.6
Apr.	....	3660	133.4	141.1	119.8	100.0
May	....	3265	118.8	165.8	93.4	99.0
June	....	2946	107.3	128.1	95.4	107.5
July	....	2750	100.4	150.0	84.7	106.5
Aug.	....	2840	103.5	147.7	84.0	96.0
Sept.	....	2710	98.8	126.4	83.1	96.7
Oct.	....	2610	95.0	190.8	77.1	93.0
Nov.	....	2410	87.6	110.5	72.7	87.8
Dec.	....	2740	99.8	140.5	75.1	92.0
1909.						
Jan.	 511,500	3285	119.0	179.5	89.7	98.0
Feb.	....	4155	150.5	270.0	93.5	96.4
Mar.	....	3915	141.9	203.0	113.5	91.9
Apr.	....	3575	129.5	206.5	108.7	91.1
May	....	3200	116.1	178.0	90.3	91.6
June	....	3330	120.8	181.3	86.8	95.5
July	....	2775	100.7	138.2	88.4	96.9
Aug.	....	2781	100.9	164.0	83.7	93.8
Sept.	....	3116	113.0	184.5	86.3	88.9
Oct.	....	2616	94.9	124.3	75.9	86.7
Nov.	....	2950	107.0	272.7	73.1	84.7
Dec.	....	3500	126.9	213.0	97.0	88.0

TABLE 21.

Relation of Quantity of Sewage to Water Consumption, North Metropolitan Sewer District, Boston, Mass.

(Based on total population of district.)

Year.	Precipitation, inches.	Avg. sewage flow, gals. per capita.	Avg. water consumption, gals. per cap.	Ratio sewage to water, %.
(1)	(2)	(3)	(4)	(5)
1904	42.82	121.5	96.0	126.6
1905	42.31	113.5	98.1	115.7
1906	44.48	119.4	97.4	122.6
1907	44.38	129.6	102.7	126.2
1908	36.15	119.0	99.2	120.0
1909	41.75	118.4	92.0	128.7
Average				123.3%

34 Similar data, based upon the number of people actually connected with the sewer system, Table 22, show a ratio of sewage flow to water consumption much higher than where the entire population is used as the basis of calculation. This ratio varies from 140 to 162%. In considering these figures, however, it should be borne in mind that those buildings and industries most needing sewers, and therefore first accom-odated, are usually the ones having the greatest quantity of wastes to dispose of. The outlying and scattered population, which is not supplied with sewage facilities, would probably not use as large a quantity of water, or have as large a quantity of sewage to be disposed of, as the denser population and the manufacturing and mercantile districts.

TABLE 22.

Relation of Quantity of Sewage to Water Consumption, North Metropolitan Sewer District, Boston, Mass.

(Based on number of persons connected with sewer system.)

Year.	Avg. sewage flow per capita, gals. per day.	Avg. water consumption per capita, gals. per day.	Sewage to water, %.
(1)	(2)	(3)	(4)
1904	156	96.0	162.5
1905	145	98.1	147.9
1906	151	97.4	155.0
1907	152	102.7	148.0
1908	139	99.2	140.1
1909	136	92.0	147.8

It is interesting to note that in spite of the fact that large tributary areas are provided with combined sewers the average
35 quantity of sewage seems to bear little or no relation to the average rainfall. This may be due in part to the small size of the intercepter, which has little capacity in excess of the requirements for fair weather and can therefore, carry only a very small quantity of storm water.

While the actual measurements of sewage are usually in excess of the measurements of water furnished to the same population, it should not be assumed that all of the water supplied to the community is delivered to the sewers. In fact, there are several days in the course of the year when the average sewage flow is actually less than the water supply. In January, 1904, August, 1905, August and September, 1906, August and July, 1907, and November, 1908, the average flow of sewage for the entire month was less than the average quantity of water supplied to the tributary population.

The sewage of a community is made up not only of the water received from the water supply, but also of ground water leaking into the sewers, storm water leaking through manhole covers, industrial and mercantile wastes, (the supply for which is obtained from sources other than the municipal supply), and storm water, where the sewers are built to receive storm water as well as sewage. It not infrequently happens in districts provided with separate sewers, that connections are made, with or without authority, through which roof water, and sometimes the drainage of areas is admitted.

An effort has been made to estimate the average quantity
36 of sewage flowing in the North Metropolitan Intercepter, exclusive of storm water, for certain months during which the rainfall was low, and in which the ground water also might be expected to be low. To aid in these studies, Fig. 9 has been prepared. The solid line represents the actual recorded quantity of sewage pumped, while the dotted lines indicate the estimated quantity of sewage excluding the storm water. By eliminating the quantities above the dotted lines, an approximation has been made of the average flow of sewage, exclusive of the run-off from storms. In the case of September, 1906, this quantity amounted to 44.8 million gallons per day. The water consumption for the same period of time was 48.8 million gallons per day. The quantity of sewage was therefore 91.9% of the quantity of water supplied to the community. Similar computations were made for six other dry months, with the results given in Table 23.

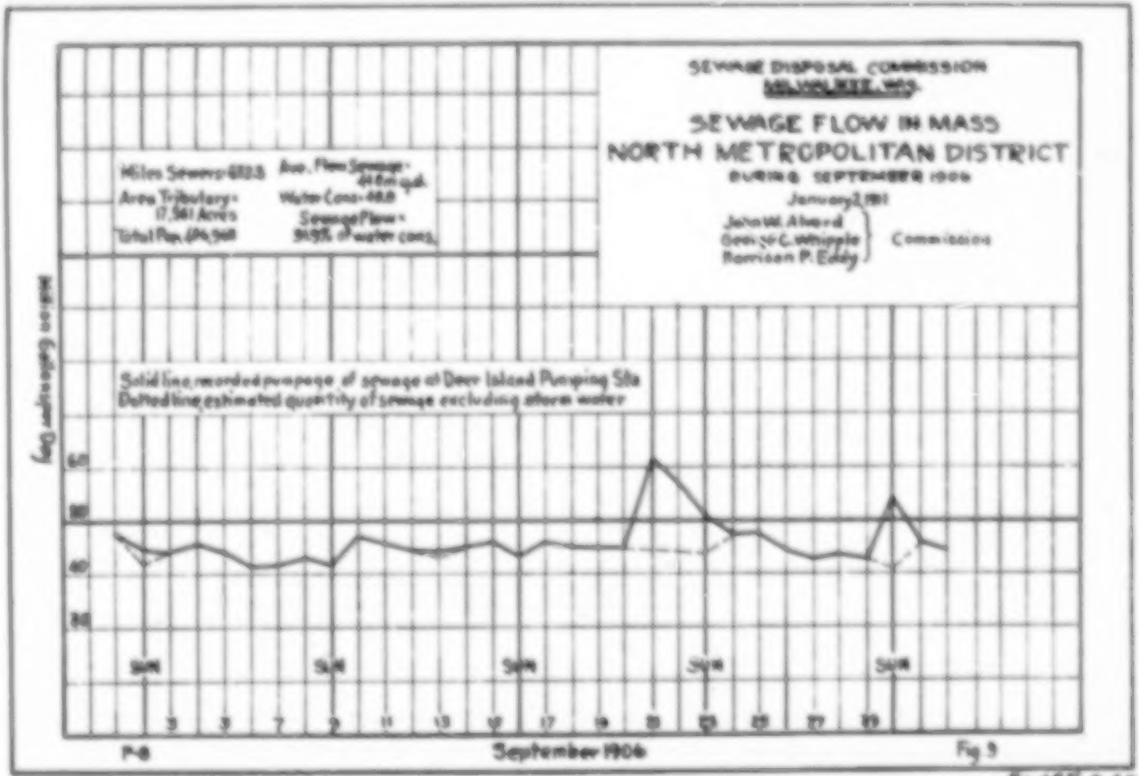
TABLE 23.

Ratio of Sewage Flow to Water Consumption During Dry Weather.

(North Metropolitan Sewer District, Boston, Mass.)

Date. (1)	Relation of sewage flow to water consumption. (2)
August, 1904	96.1%
" 1905	95.8
" 1906	94.3
Sept., 1906	91.9
" 1908	100.9
Oct., 1908	93.7
Nov., 1908	98.0

(Here follows diagram, Fig. 9, marked page 37, Complainants' Exhibit 158.)



SEWAGE DISPOSAL COMMISSION
MILWAUKEE, WIS.
SEWAGE FLOW IN MASS
NORTH METROPOLITAN DISTRICT
DURING SEPTEMBER 1906
John W. Alvord
George C. Whipple
Harrison P. Eddy
Commission
Solid line, recorded pumpage of sewage at Deer Island Pumping Sta
Dotted line, estimated quantity of sewage excluding storm water
Million Gallons per Day
60
50
40
30
SUN
SUN
SUN
SUN
SUN
3
5
7
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11
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15
17
19
21
23
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27
29
P-8
September 1906
Fig 9

38 In all cases, the quantity of sewage doubtless includes some ground water, and the usual quantity of manufacturing wastes, the water for which is derived from sources other than the water supply.

As has been pointed out, ground water stands or flows at a higher elevation in the spring than during other seasons of the year. A study of the records of the North Metropolitan sewer for the month of April in several years throws some light upon the average quantity of leakage which may be expected during that month. In a manner similar to that already described in determining the ratio of dry weather flow of sewage to the water consumption, Fig. 10 has been plotted, showing by the solid lines, the sewage pumped for each day of the month. The dotted lines indicate the probable quantity of sewage eliminating the storm water. Taking April, 1906, as an illustration, it appears that the quantity of sewage averaged 70.2 million gallons per day. Ninety per cent of the water consumption, which has been found to be equivalent to the dry weather flow in the intercepter, was 40.2 million gallons daily, leaving a surplus at this time of 30 million gallons per day. As the quantity of manufacturing wastes for the district were included in figures upon which the estimate of the dry weather flow of sewage (90% of water consumption) was based, it is evident that this difference of 30,000,000 gallons per day represents the quantity of ground water in excess of that present in very dry weather, which found its way by

39 infiltration into the sewers. As there were 652.5 miles of sewers tributary to the system at that time, the excess leakage averaged 46,000 gallons per day per mile of sewers. The tributary area was 17,561 acres, making the average daily leakage, (in excess of that during very dry weather), say 1,707 gallons, while the daily leakage per capita was 61.6 gallons.

(Here follows diagram, Fig. 10, marked page 40, Complainants' Exhibit 158.)

The month of April in four different years has been studied in a similar manner, and the results are given in Table 24.

Table 24.

Estimated Average Daily Quantity of Ground Water Leaking into North Metropolitan Sewer System in April, Boston, Mass.*

	Leakage, gals. per mile of sewers.	Leakage, gals. per acre.	Leakage, gals. per cap.	Rainfall. Inches.	Rainfall. Previous month.
(1)	(2)	(3)	(4)	(5)	(6)
April, 1904......	47,900	1,727	62.7	9.28	2.84
April, 1905......	33,700	1,240	44.5	2.63	2.86
April, 1906......	46,000	1,707	61.6	2.32	7.32
April, 1909......	27,600	1,056	38.3	3.92	3.90

From this table, it appears that the average quantity of leakage in April in excess of that in August, varied from 27,600 to 47,900 gallons per day per mile of sewer, and from 1,056 to 1,727 gallons per day per acre. The largest quantity of leakage was in April, 1904, when the rainfall for the month was 9.28 inches. The next largest quantity was in April, 1906, when the rainfall was but 2.32 inches; but during the previous month there was a rainfall of 7.32 inches, which undoubtedly had much to do with the high ground water of the month in question.

41 To these quantities should be added the leakage during the dry weather, when the sewage was found to be equivalent to 90% of the water consumption. It is extremely doubtful if this leakage ever falls below 10,000 gallons per day per mile of sewers. Adding 10,000 gallons per mile to the quantities given in Table 24, the total average leakage per acre and per capita per day would be as shown in Table 25.

* In excess of ground water leakage during month of August.

Table 25.

Estimated Average Daily Quantity of Ground Water Leaking into North Metropolitan Sewer System.

(Assuming that leakage during driest months = 10,000 gals. per day per mile of sewer.)

Month.	Leakage in gallons per day per		
	Mile of sewer.	Acre.	Capita.
(1)	(2)	(3)	(4)
April, 1904	57,900	2,089	76
" 1905	43,700	1,607	58
" 1906	56,000	2,078	75
" 1909	37,600	1,469	52

In considering these figures, it must be remembered that they are average figures for the entire month, and it can readily be seen that the maximum quantity of leakage would be far in excess of this quantity. On the other hand, the tributary area is very completely sewered—23.8 miles of sewers per square mile—and many of the trunk sewers lie in wet ground and were built at a time when less care was taken to exclude ground water than at present. In calculating this area, only the districts directly tributary to sewers now built are included, and as they are located within a much larger tributary but unsewered area, the unit leakage is undoubtedly higher than will be the case when the entire district is completely sewered.

42 Miles of Sewers Per Unit of Area.

Table 26 compiled from data furnished in the special report of the United States Census Bureau upon "Statistics of Cities for 1905," shows the number of miles of sewers existing in various cities of the United States at that time. It appears that Boston had the greatest mileage,—18.4 miles of sewers per square mile of area,—while Milwaukee was second with 17.2 miles. These figures undoubtedly include areas somewhat suburban in nature which were not completely sewered. It would seem therefore, that an estimate of about 17 miles of sewers per square mile would be reasonable for Milwaukee in the future.

Estimate of Ground Water Reaching Sewers in Milwaukee.

There are certain portions of Milwaukee which yield considerable ground water, and others in which the soil is of blue clay and hardpan where scarcely any water is met in excavations for sewers. Comparatively small areas are low and lie adjacent to the rivers, but as a rule the land rises rapidly from the rivers. There are no indications of unusual leakage here, and provision for leakage amounting at times to [illegible]0,000 gallons per mile of sewer would appear to be ample.

We have assumed an allowance of 1,960 gallons per day per acre for maximum leakage. If the extent of the sewers is taken as 17 miles per square mile, this allowance for ground water corresponds to a leakage of 73,700 gallons per mile of sewers. So great a
43 quantity of leakage will be of comparatively short duration, but the studies of the records of the North Metropolitan System, and experience in other places indicates that at least as much as one-half this quantity or 980 gallons per day, per acre may be expected for a month or more at a time. These allowances may be summarized as follows:

Maximum Rate of Leakage.

1960 gals. per day per acre, or approximately 0.003 cu. ft. per second per acre.

Rate of Leakage Probable for One or Two Months at a Time.

980 gals. per acre per day, or approximately 0.0015 cu. ft. per second per acre.

Quantity of Leakage at Maximum Rate, 1910.

$$\frac{(1960 \times 14{,}374)}{373{,}857} = 76 \text{ gals. per day per capita.}$$

Quantity of Leakage Probable for One or Two Months at a Time.

38 gallons per capita.

44 TABLE 26.

*Miles of Sewers Per Square Mile of Area in Various Cities—1905.**

Name.	Population, 1905.	Area in sq. miles (ap-(proximate).	No. of miles of sewers.	Miles of sewers per sq. mile.
Boston, Mass.	595,380	38	700.6	18.4
Milwaukee, Wis.	312,948	22	379.8	17.2
Allegheny, Pa.	142,848	7	111.5	16.4
Detroit, Mich.	325,563	36	561.7	15.6
Memphis, Tenn.	121,235	15	221.0	14.7
Newark, N. J.	283,289	16	232.4	14.5
Rochester, N. Y.	182,022	19	241.3	12.7
Pittsburgh, Pa.	364,161	29	365.7	12.6
Buffalo, N. Y.	376,914	40	489.0	12.2
Jersey City, N. J.	232,699	13	115.5	11.9
Providence, R. I.	198,635	18	213.3	11.8
Syracuse, N. Y.	117,129	16	118.2	11.4
Kansas City, Mo.	179,272	26	282.0	10.8
Cleveland, Ohio	437,114	39	412.7	10.6
Columbus, O.	142,105	16	168.2	10.5
St. Louis, Mo.	636,973	61	609.2	9.9
Chicago, Ill.	1,990,750	183	1633.0	9.2
Philadelphia, Pa.	1,417,062	128	1041.2	8.1
Washington, D. C.	302,883	60	484.4	8.1
Toledo, O.	155,287	25	191.6	7.6
San Francisco, Cal.	......	46	332.8	7.2
Omaha, Neb.	120,565	24	158.8	6.6
Cincinnati, O.	343,337	42	263.2	6.2
Louisville, Ky.	222,660	20	122.1	6.1
New Haven, Conn.	119,027	18	105.4	5.8
Indianapolis, Ind.	212,198	30	162.1	5.4
New York, N. Y.	4,000,403	327	1752.7	5.4
Denver, Colo.	150,317	58	307.8	5.3
Scranton, Pa.	116,111	19	95.0	5.0
Worcester, Mass.	128,135	37	176.8	4.8
Los Angeles, Cal.	......	43	203.9	4.7
Minneapolis, Minn.	261,974	49	200.4	4.1
St. Paul, Minn.	197,023	52	210.2	4.0
New Orleans, La.	309,639	200	350.0	1.7
Baltimore, Md.	546,217	31	46.6	1.5

* From United States Census Bureau special Report of "Statistics of Cities, 1905."

45 Discussion of Results of Measurements of the Flow of Sewage from District No. 47, Milwaukee.

This district, comprising 358 acres, is residential in character and no industrial or mercantile wastes are known to be discharged into the sewer. It is completely sewered and practically built up, the density of population being 30.7 persons per acre, corresponding to a total population of 11,000.

The gaugings, covering a period of four days, were made in the 72 inch sewer in 15th Street, near the northerly line of Grand Avenue. The district tributary to this sewer lies between the northerly line of Grand Avenue and the southerly line of Walnut Street, and, in a general way, between 14th and 23rd Streets.

The results of these sewer gaugings have been summarized as follows.

TABLE 28.

Sewer Gaugings.

	Total quantity.	
Monday (8 A. M. Oct. 24 to 8 A. M. October 25)	950,000 gals.	
Tuesday (8 A. M. Oct. 25 to 8 A. M. October 26)	911,000 "	
Wednesday (8 A. M. Oct. 26 to 8 A. M. October 27)	884,000 "	
Thursday (8 A. M. Oct. 27 to 8 A. M. Oct. 28)	931,000 "	per day
Average	919,000 "	" "

Using these quantities as a basis of calculation it appears that the average flow of sewage per capita was as follows:

46 TABLE 29.

Sewage Flow Per Capita Per Day.

(30.7 persons per acre.)

Monday	86.4 gals.
Tuesday	82.8 "
Wednesday	80.4 "
Thursday	84.6 "
Average	83.5 "

The average quantity of sewage found to be flowing in this sewer was 83.5 gallons per capita per day. This consists of ground water and that portion of the water supply discharged into the sewers.

It has some times been suggested that an indication of the quantity of ground water flowing in sewers can be obtained by assuming that the minimum rate of flow during the night is equivalent to the ground water infiltration. Obviously the quantity of ground water finding its way into the sewers is the same at night as during the day, and it is also true in many cases that the quantity of sewage actually contributed to the sewers during certain hours of the night is extremely small, if not nil. As this is a residential district, it is probable that no serious error will result from the assumption that in this case the minimum rate of flow during the night represents the quantity of ground water leaking into the sewer system. The minimum rate of flow on each of the days when gaugings were made, reduced to gallons per capita, was found to be as follows:

47 TABLE 30.

Minimum Rate of Flow.

Tuesday (12:30 A. M.)	31.1	gals. per Cap. per day.
Tuesday (11:00 P. M.)	40.5	" " " " "
Thursday (1:00 A. M.)	38.2	" " " " "
Friday (1:00 A. M.)	39.1	" " " " "
Average	37.2	

The rate of flow was smallest at 12:30 A. M. Tuesday when the quantity of water flowing in the sewer was equivalent to 956 gallons per acre per day, corresponding to 31 gallons per capita per day. If it is assumed that this quantity represents the ground water, the remainder of the flow would represent the water supply reaching the sewer, amounting to 52.5 gallons per capita per day.

The fluctuation in the maximum rate of flow was very marked, being from 133 to 207 gallons per capita per day. The maximum rate of flow on each of the days when gaugings were made, was found to be as follows:

TABLE 31.

Maximum Rate of Flow.

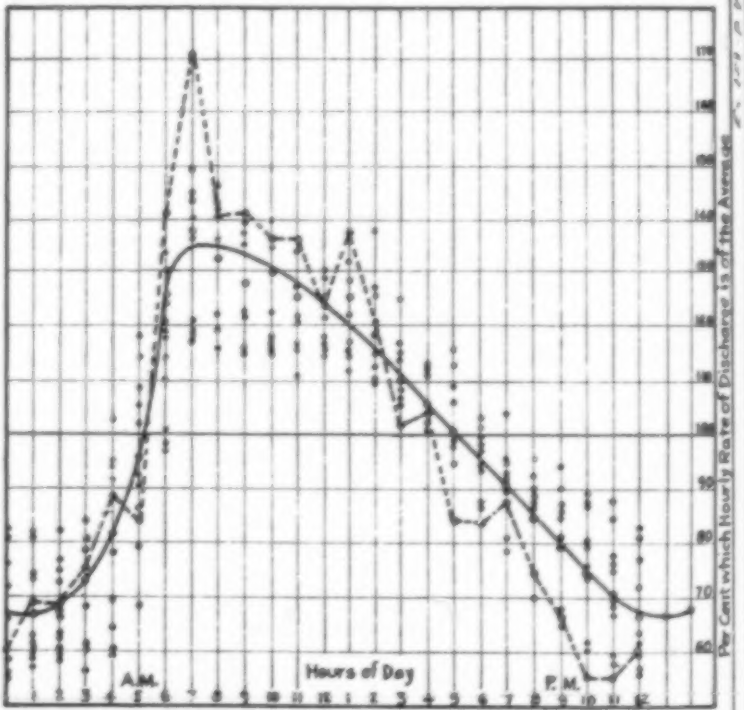
Monday (10:30 A. M.)	207	gals. per cap. per day.
Tuesday (10:30 A. M.)	133	" " " " "
Wednesday (8:00 A. M.)	149	" " " " "
Thursday (8:00 A. M.)	168	" " " " "
Average	164	gals. per cap. per day.

The ratio of the average maximum rate of flow to the average daily rate of flow $\left(\frac{164}{83.5}\right)$ is 1.96; that is, the average maximum rate

of flow was found to be nearly double the average daily flow.
48 This average maximum rate, however, is obtained by averaging the maximum rates of flow found on all of the four days when measurements were taken. These maximum rates, however, did not occur at the same hour of the day in each case, so that somewhat different results would be obtained by averaging the rates of flow for the same hour and selecting the maximum from this set of averages. The broken line, Fig. 11, shows the average rate of flow for each hour from District 47, for the four days covered by these gaugings.

This district is comparatively small in area, and the sewers are short and have rather steep grades. The longest sewer is about 1½ miles in length, and most of them are considerably shorter. The district is approximately rectangular in shape, about 5,000 feet long and 3,000 feet wide, on the average. On account of the size, shape, topography and residential character of the district, the measurements of the sewage show a fluctuation corresponding closely with that which would be expected. The fluctuation in the flow from the entire city at the outlet of the intercepting sewer will be very different from that of this or any other district, because of the equalizing effect due to difference in the length of trunk sewers in different districts, difference in the character of the districts, and storage in the intercepting sewers; so that the maximum rate of flow in and from the intercepting sewers will not be the same as that in the trunk Sewer of District No. 47.

(Here follows diagram, Fig. 11, marked page 49, Complainants' Exhibit 158.)



MILWAUKEE, WIS. Oct. 24-28, 1910
WORCHESTER, MASS. Nov. 13, 1909, Mar. 21-21, 1910
MARLBORO, MASS. Typical Average
TORONTO, CANADA 1901, 1906, 1908.
GLOVERSVILLE, N.Y. Oct. 30, 1906, Sept. 12, 1907
EAST ORANGE, N.J. Mar. 16-17, 1910
BIRMINGHAM, ENG. Aver. 2 years 1906

Full line is average of all gagings - points shown thus o
Dotted line is average of Milwaukee gagings, District #47 points shown thus •

SEWAGE DISPOSAL COMMISION

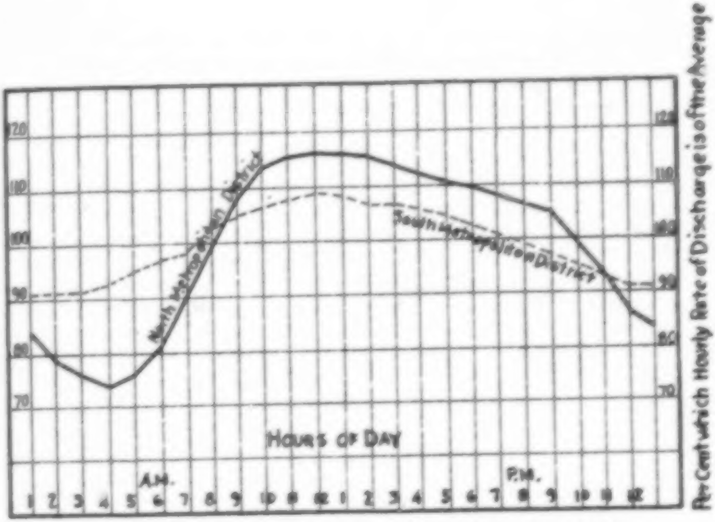
MILWAUKEE, WIS.

HOURLY VARIATION IN FLOW OF SEWAGE IN VARIOUS CITIES

December 20, 1910

John W. Alvord
George C. Whipple
Harrison P. Eddy
} Commission

E-10 Fig. 11



NORTH METROPOLITAN DISTRICT Average of the week begining November 2,1908.
SOUTH " " " " " " " " 8 1909

NORTH METROPOLITAN SEWER Gaged near Chelsea and Everett line.
SOUTH " " " in Quincy

Hours apply to North metropolitan District only
South Metropolitan curve moved forward 8 hours.

SEWAGE DISPOSAL COMMISSION
MILWAUKEE, WIS.

HOURLY VARIATION IN FLOW OF SEWAGE
IN MASS. METROPOLITAN DISTRICTS

December 28, 1910.

John W. Alvord
George C. Whipple } Commission
Harrison P. Eddy

E-11

Fig. 12.

The relative hourly rates of flow as obtained by measurements taken in various cities, are indicated by the dots upon Fig.
50 11. The results of averaging these measurements are indicated on the diagram by the small circles. The solid line is a curve drawn through many of the average points, and presents fairly well the average hourly fluctuation in the flow of sewage. In preparing this diagram, allowance has been made for the time consumed by the sewage in flowing to the gauging stations, and the gaugings have been so arranged that the early morning rise in flow shall come at substantially the same time in all of the cities. From this diagram it appears that the maximum rate of flow is, under average conditions, about 1.35 times the mean flow.

In Fig. 12 curves have been plotted showing the hourly fluctuation in the rate of flow in the North and South Metropolitan intercepting sewers, Boston. From these curves it appears that the maximum rate of flow in the North intercepter is only about 1.18 times, and in the South intercepter 1.09 times the average rate. In considering these curves it should be remembered that the intercepting sewers are very long and receive the sewage of many different cities and towns, which fact doubtless accounts for the smaller variation in flow than is shown by the curve in Fig. 11. It seems probable also that the fluctuation in the rate of flow from the City of Milwaukee would be somewhat greater than that of the North Metropolitan District.

(Here follows diagram, Fig. 12, marked page 51, Complainants' Exhibit 158.)

The average rate of flow through the day time, say from 9 A. M. to 5 P. M. in District 47, for the four days when the flow was gauged, was 1.33 times the average rate of flow for 24 hours.

52 Industrial Wastes.

Milwaukee is essentially a manufacturing city, being fortunate in the possession of many and varied industries. Several of these produce comparatively large quantities of waste liquors which are now discharged into the sewers or rivers. No effort has been made to obtain a complete census of the quantity of industrial wastes, although several of the manufacturies known to produce large quantities of waste liquors was visited, samples of the wastes collected for analysis and estimates made of the quantity of water used, as an index to the quantity of wastes which will be likely to be discharged into the sewers. The results of this investigation, so far as they pertain to the quantity of wastes are given in Table 32.

TABLE 32.

Quantities of Water Used by Several Manufactories in Milwaukee.

Plant. (1)	From private water supply. (2) (Gals. per day.)	City water. (3)
Plankington Packing Co.	400,000	....
Layton Packing Co.	200,000	Boilers only
Bodden " "	45,000	55,000 gals.
Gumz " "	80,000	per day
Pabst Brewery	1,000,000 to 2,000,000	....
Schlitz "	2,000,000	1,000,000
Blatz "	500,000	600,000
Pfister & Vogel's Tannery	800,000	400,000
Trostel & Sons	600,000	....
American Hide & Lea. Co.	350,000	....
Milwaukee Coke & Gas Co.	475,000	....
Total	7,450,000	gals. per day.
Johns-Manville Asbestos Works		500,000 (not now within city limits).

53 This quantity of water taken from private supplies is equivalent to about 20 gallons per capita per day. There are no doubt many other industrial plants provided with water from private sources, so that the total of such supplies will materially exceed this quantity; in fact, a consumption of 50 or 60 gallons per capita per day from private sources, is not unreasonable. The greater part of this water is likely in the future to be discharged into the sewers after it has been used, although this may not be true at the present time.

Additional light is thrown upon the quantity of industrial wastes likely to be received into the sewers by a series of gaugings of the flow in the trunk sewers in 1910.

Discussion of Measurements of Flow in Trunk Sewers.

During April and May, 1910, Mr. George L. Thon of Mr. Alvord's office, made gaugings of most of the sewer outlets. The results of these gaugings are given in Table 33.

The district numbers, gross areas, and sewered areas of the various sewer districts are given for reference in Table 34.

The only sewers in which the flow was not gauged were those in districts 3, 4, 40 and 42. The total of the quantities of sewage found to be flowing at the hours when gaugings were made was at the rate of 82,500,000 gallons per day. This quantity was produced on a total of 10,803 acres of sewered area, and is equivalent to 7,640 gallons per acre per day.

4303

38—Ex. 158

TABLE 33.

Estimated Quantities of Industrial Wastes from Each District Based on Gaugings and Computations.

District No.	Popul. per acre of sewered area.	Est. of total water supply contributed plus ground water at time of gaugings, gals. per day.	Measured flow of sewage, gals. per day.	Diff. assumed to be max. rate mfg. wastes, gals. per day.	Total mfg. wastes No. 5 x 16/24 / 0.75 gals. per day.	Total industrial wastes. Gals. per day per acre of sewered area.	Total industrial wastes. Gals. per capita per day.
Sewers Flowing into Milwaukee River:							
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1	16.6	465,300	97,000	....	....	......	...
2	16.6	1,318,000	2,338,000	1,020,000	566,600	1,479	89
5	15.7	561,000	1,770,000	1,209,000	671,800	3,359	214
6	33.5	607,200	732,000	124,800	68,900	510	15
7	38.3	233,400	364,000	130,600	72,550	1,500	39
8	34.9	176,000	1,085,000	909,000	505,200	13,020	373
9	29.9	210,500	169,000	....	....	......	...
10	29.9	236,300	870,000	633,700	352,000	6,170	206
11	29.9	182,000	980,000	797,400	442,600	9,900	331
12	28.6	111,200	486,000	374,800	208,400	7,550	264
13	28.0	484,200	2,195,[illegible]00	1,710,000	950,000	7,780	278
14	27.1	79,950	538,000	458,050	254,400	12,350	456
15	27.1	87,750	603,000	515,250	286,100	12,660	467
16	27.1	88,950	227,000	138,050	76,700	3,355	124
17	27.1	132,700	91,000	....	....	......	...
18	27.1	187,300	78,000	....	....	......	...
19	22.2	75,650	55,000	....	....	......	...
21	22.2	47,900	603,000	555,100	308,300	22,000	991
43	32.5	357,300	1,950,000	1,592,700	884,200	10,870	334
44	32.5	154,000	1,650,000	1,496,000	831,000	23,680	728
46	29.6	476,000	3,480,000	3,004,000	1,668,000	14,430	487
49	38.6	254,500	552,000	297,500	165,100	3,223	84
50	45.9	427,000	603,000	176,000	97,700	1,294	28
51	50.8	734,300	6,650,000	5,915,700	3,285,000	27,370	538
52	46.7	2,065,000	6,810,000	4,745,000	2,636,000	7,320	157
53	31.1	4,238,000	5,030,000	792,000	439,900	444	14
54	32.6	2,617,000	3,100,000	483,000	268,300	479	15

56	24.5	821,000	525,000	....	....	......	...
57	45.8	546,500	3,050,000	2,503,500	1,392,000	14,390	314
Sewers Flowing into Menomonee River & Intercepting Sewer:							
20	22.2	266,000	168,500	....	....	......	...
23	22.3	187,200	422,000	234,800	130,400	2,388	107
24	22.6	154,200	217,000	62,800	34,750	780	34.5
25	22.6	48,500	213,800	165,300	92,000	6,550	290
26	22.7	143,200	427,500	284,300	157,750	3,820	168
27	19.7	650,000	434,000	....	....	......	...
28	22.1	825,000	434,000	....	....	......	...
29	23.3	592,000	1,630,000	1,038,000	577,500	3,436	147
30	29.4	1,584,000	1,150,000	....	....	......	...
45	29.2	404,000	1,430,000	1,026,000	570,000	5,765	197
47	30.6	1,832,000	923,000	....	....	......	...
48	32.9	6,780,000	8,690,000	1,910,000	1,061,000	694	21
55	27.3	5,840,000	3,460,000	....	....	......	...
Sewers Flowing into the Kinnickinnic River:							
22	22.2	257,200	1,447,500	1,190,300	661,500	8,795	396
31	27.0	833,500	852,250	18,750	10,420	48	2
32	22.2	185,200	71,100	....	....	......	...
33	21.6	419,500	2,198,000	1,778,500	986,500	9,395	435
34	21.5	269,200	627,000	357,800	198,700	2,474	115
35	38.	920,200	763,000	....	....	......	...
36	42.3	4,810,000	7,440,000	2,630,000	1,462,000	1,792	42
37	39.5	1,209,000	2,250,000	1,041,000	578,000	2,698	68
38	18.5	299,200	316,900	17,700	9,840	1,008	55
39	21.5	256,600	129,300	....	....	......	...
41	15.4	341,000	132,500	....	....	......	...

55 Applying this quantity to the total sewered area of the city (12,137.3 acres), the corresponding flow of sewage would be at the rate of 92,750,000 gallons per day, which represents the total quantity produced at this time in the day (say between 9 A. M. and 4 P. M.), by all districts, including those which were not gauged.

Assuming that 70 gallons per capita per day of the municipal water supply are delivered to the sewers in the form of sewage, as previously discussed, the present population of 373,857 people would contribute 26,170,000 gallons per day.

April and May are months during which the ground water is generally found to be high, and it would seem to be a conservative assumption that the average leakage during the period covered by these measurements amounted to 37,000 gallons per day per mile of sewers, or 980 gallons per acre per day. (The analysis of measurements of flow in District No. 47 showed 560 gallons per day per acre in October.) While the entire City is not sewered, there is little doubt that the ground water from a larger area than that actually sewered is received into the sewers, and for that reason it is fair to use, in these calculations, the actual area within the City limits (14,374 acres). On this basis the quantity of ground water finding its way into the sewers would be 14,090,000 gallons per day, which added to the water supply contributed, would amount to 40,260,000 gallons per day, as the amount of domestic sewage and ground water.

56 Assuming that the flow of ground water and water supply contributed during that portion of the day within which the guagings were made,—from 9 A. M. to 4 P. M.—was 135% of the average flow for the twenty-four hours, (based on measurements of flow in district No. 47), the flow during this period would be at the rate of 54,350,000 gallons per day. Deducting this quantity from the rate of flow calculated from the gaugings, 92,750,000, there is found to be a difference of 38,400,000 gallons per day, which represents the rate of flow of industrial wastes during these hours of the day.

By far the larger portion of industrial wastes are discharged during ten hours of the day. Assuming that ¾ of the total quantity represents this portion, and that the discharge is uniform during the ten hours, it appears that 16,000,000 gallons ($10/24 \times 38.40$ m. g. d.) is equivalent to ¾ of the quantity produced per day, and that the total quantity would be 21,350,000 gals. per day, equivalent to 57.2 gallons per capita.

The result of these measurements and the calculations based upon them, to the effect that the quantity of manufacturing wastes discharged into the sewers amounts to about 21 million gallons per day, does not seem unreasonable. It should also be remembered that some of the industrial wastes are now discharged into the rivers. Such of these wastes as may tend to seriously pollute the rivers should be diverted from them into the sewers as soon as the intercepters are put into use.

57 The fact that a single industrial plant may discharge as great a quantity of wastes as 3,000,000 gallons per day, equivalent to nearly 10 gallons per capita for the entire population

of the city, is further evidence that an estimate of 60 gallons per capita per day of industrial waste from the entire city is not unreasonable.

Milwaukee is very favorably situated to provide a cheap supply of water for industrial purposes, as plants located near any of the rivers and canals can secure water from them. As soon as the sewage is intercepted this water will be of fairly good quality, and can be used without purification for many of the rougher purposes, and where a water of comparatively high degree of purity is necessary, as for dyeing delicate tints, the river water can be purified locally at comparatively small expense. It seems logical therefore, that Milwaukee should continue to be a favorable location for industries requiring large quantities of water, and that, in estimating the future quantity of sewage to be purified, provision should be made for as great a quantity of industrial wastes as appears to be produced at the present time, and it should further be assumed that, as at present, the industries will be supplied with water largely from wells and from the rivers.

In columns 7 and 8, Table 33, is recorded the quantity of industrial wastes per acre and per capita, respectively, calculated
58 as being produced in the various districts. The calculations have been made for each district, by the method just described in calculating the total quantity of industrial wastes. It will be noticed that in a few of the districts, as for example Districts 1, 17, 18 and 19, the quantity of sewage measured was not in excess of the estimated quantity of water supply contributed and ground water flowing in the sewers at the time the measurements were taken. These districts are, we believe, without exception, residential in character, so that industrial wastes were not to be expected. The quantity of industrial wastes from the different districts varies from 2 to 991 gallons per capita per day. The districts in which this unit quantity is found to be particularly high are those which are known to contain numerous industrial or mercantile houses, and therefore, it is considered that the results of this calculation are reasonable and reliable. The maximum quantity of industrial wastes produced per acre of sewered area was 27,370 gallons per day for District 51. The quantities vary greatly.

Summary of Calculations and Estimates of Quantities of Sewage.

Summarizing the foregoing calculations and estimates, the quantity of sewage produced in 19-0 would be made up as follows:

TABLE 35.

Quantity of Sewage, 1910.

	Mil. gals. per day.	Gals. per cap. per day.	% of flow.
	(1)	(2)	(3)
Water supply contributed	26.17	70	42.4%
Ground water*	14.09	38	23.
Industrial wastes	21.35	57	34.6
Total	61.61	165	100.0

*When leakage is moderate.

59 This quantity, equivalent to 165 gallons per capita, may be expected for periods of one or two months in the spring, and for periods of several days, possibly a month at a time, occasionally during other seasons of the year. It is probably somewhat above the annual average quantity which will be delivered to the disposal works.

The water supply contributed in the form of sewage is estimated to be 42% of the total sewage flow, and the manufacturing wastes nearly 35%. The quantity of sewage estimated for 1910,—61,610,000 gallons per day,—is 1.58 times the daily average water consumption for the year. It should be remembered that this estimate includes a moderate amount of leakage, though not more than may be expected for one or two months at a time. This estimate is therefore probably somewhat greater than the average quantity of sewage actually discharged into the rivers. It is interesting to note, in this connection, that the quantity of sewage in the North Metropolitan District of Boston, for the years 1904 to 1909 inclusive, was 1.23 times the water consumption.

There will be comparatively short periods of time, say from one to two weeks' duration, during which the quantity of ground water reaching the sewers will be considerably in excess of that included in the foregoing estimate of 61.61 million gallons per day. Assuming that this excess quantity of ground water would be equal to that already included, (980 gallons per acre), the total sewage flow would become 75.7 million gallons per day, equivalent to 286 gallons per capita.

60 Neither of these estimates includes any storm water. The estimates of the quantity of ground water per acre and of manufacturing wastes per capita are uniform throughout the period of forty years considered in this report. The quantity of water supply contributed has been gradually increased as previously explained. The population and the area of the City are increased so that the total quantity of sewage per capita varies from time to time in accordance with the growth of the city and the increase in the quantity of water consumed. The unit and total quantities used in and resulting from these calculations are given in Tables 36 to 37 inclusive.

The basis of design of the works for the clarification or purification of the sewage should be the average quantity of sewage per day when leakage is moderate, which has been estimated at from 165 to 182

gallons per capita, equivalent to 100,000,000 gallons in 1930 and 155,000,000 in 1950, calculated upon the estimated population for those years. Due consideration should be given, however, to the fact that very much larger quantities of sewage will be received in time of storm, and that there will be a material fluctuation in the rate of flow from day to day, and from hour to hour during the day. The capacity of the intercepting sewers, the pumping station and the outfall, cannot be based upon the average quantity of sewage, but must be proportioned according to the maximum rate of flow to be provided for.

In tables 38 and 40 are given the estimated maximum rate of flow in gallons per capita, and in million gallons per day.

61 Column 2, Table 38, gives the estimated maximum rate at which the water supply will be contributed to the sewers. It is obvious that the quantity of ground water will not vary from hour to hour during the day. It has already been explained that the maximum rate of domestic sewage flow will be about 135% of the average rate.

From Table 37, it is seen that in 1910 the estimated sewerage water supply contributed is 70 gallons per capita, and the leakage 38 gallons per capita. The total of these two items would, therefore, be 108 gallons per capita, which represents the average quantity of domestic sewage. This would be increased to 135% at times of maximum discharge, the quantity then being about 146 gallons. Deducting the ground water, 38 gallons, we have the maximum rate at which the water supply is contributed,—108 gallons per capita per day.

It has been assumed that three-quarters of the industrial wastes will be discharged in ten hours, so that the maximum rate of discharge will be 103 gallons per capita, (column 3, Table 38). Adding the maximum rate of water supply contribution, the maximum rate of industrial wastes and the leakage when moderate, it appears that in the year 1910, the estimated maximum rate of total sewage flow will be 248 gallons, and in 1950, 271 gallons per capita per day. At times when the leakage into the sewers is excessive, the maximum rate of flow is estimated to be 285 gallons and 312 gallons per capita per day in 1910 and 1950 respectively.

62 From the foregoing discussion, it is evident that if the intercepting sewers are to have a capacity sufficient for a population of 850,000 people, as estimated for 1950, they must provide for a maximum rate of flow of 312 gallons per capita daily. It is realized that these estimates are based upon somewhat unsatisfactory data, and no provision whatever is made for storm water. In view of the advisability of continuing the flushing of the rivers, and the practical impossibility of preventing the bacterial infection of the waters of the bay, and possibly the water supply, it does not seem wise to provide for the pumping, clarification and disposal into the Lake at the new outlet, of a material proportion of the storm water. It has, therefore, been decided not to attempt to collect in the intercepting sewers, large quantities of storm water, but to provide liberally for the maximum rate of flow at times when the leakage into

the sewers is excessive. Accordingly, the capacity of the interceptors has been based on an estimated flow at such times of 350 gallons per capita, or 38 gallons in excess of the estimate for 1950, given in column 7, Table 38. The quantity of sewage for which provision is made, will therefore, be 297,500,000 gallons daily (350 gallons per capita from a population of 850,000 people).

While no provision is made for storm water after the city reaches a population of 850,000, it is obvious that from the time the interceptors are built until this population is reached, there will be a surplus capacity which will be available for storm water. In
63 times of moderate flow, as during the warmer months of the year, the amount of this surplus capacity will be that given in Column 3, Table 41.

64

Table 36.

Population, Area and Water Consumption Used in Estimating Quantity of Sewage.

Year.	Population of city.	Area of city, in acres.	Water consumption, gals. per cap. per day.
(1)	(2)	(3)	(4)
1910	373,857	14,374	105
1920	475,000	19,531	110
1930	585,000	24,681	115
1940	715,000	29,844	120
1950	850,000	35,000	125

Table 37.

Units Used in Estimating Average Quantity of Sewage, in Gallons per Capita per Day.

Year.	Ave. water supply contributed.	Ave. industrial wastes.	Leakage when moderate.	Total ave. quantity of sewage when leakage is moderate.	Leakage when excessive.	Total ave. quantity of sewage when leakage is excessive.
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1910	70	57	38*	165	75**	202
1920	73	57	40	170	81	211
1930	75	57	41	173	83	215
1940	80	57	41	178	82	219
1950	85	57	40	182	81	223

* Based on 980 gals. per acre per day.
** Based on 1960 gals. per acre per day = 200% of average.

TABLE 38.

Units Used in Estimating Maximum Rate of Flow of Sewage, in Gallons per Capita per Day.

Year.	Max. rate water supply contributed.	Max. rate industrial wastes.	Leakage when moderate.	Total max. rate of sewage flow when leakage is moderate.	Leakage when excessive	Total max. rate of sewage flow when leakage is excessive.
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1910.......	108	103	38*	248	75**	285
1920.......	112	103	40	255	81	296
1930.......	116	103	41	260	83	302
1940.......	122	103	41	266	82	307
1950.......	128	103	40	271	81	312

* Based on 980 gallons per acre per day.
** Based on 1960 gals. per acre per day = 200% of average.

TABLE 39.

Year.	Ave. water supply contributed.	Ave. industrial wastes.	Leakage when moderate.	Total ave. quantity sewage when leakage is moderate.	Leakage when excessive.	Total average quantity of sewage when leakage is excessive.
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1910..	26.17	21.35	14.09	61.61	28.18	75.70
1920..	34.41	27.20	19.12	80.73	38.24	99.85
1930..	43.80	33.40	24.20	101.40	48.40	125.60
1940..	57.20	40.80	29.22	127.22	58.44	156.44
1950..	72.25	48.80	34.30	155.15	68.60	189.45

TABLE 40.

Estimated Maximum Rate of Flow of Sewage, in Million Gallons per Day.

Year.	Max. rate water supply contributed.	Max. rate industrial wastes.	Leakage when moderate.	Total max. rate of flow of sewage when leakage is moderate.	Leakage when excessive.	Total max. rate of sewage flow when leakage is excessive.
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1910..	40.16	38.45	14.09	92.70	28.18	106.80
1920..	53.23	48.90	19.12	121.25	38.24	140.40
1930..	67.65	60.20	24.20	152.05	48.40	176.20
1940..	87.48	73.60	29.22	190.30	58.44	219.50
1950..	108.90	87.50	34.30	230.70	68.60	265.00

TABLE 41.

Surplus Capacity of Intercepters Available for Carrying Storm Water.

(Capacity of Intercepters 297.5 Million Gallons per day.)

Year.	Avg. rate of sewage flow when leakage is moderate (m. g. d.).	Surplus capacity of intercepter (m. g. d.).	Dilution of sewage at time overflow takes place.
(1)	(2)	(3)	(4)
1910	61.61	235.89	1:3.83
1920	80.73	216.77	1:2.68
1930	101.40	196.1	1:1.93
1940	127.22	170.28	1:1.34
1950	155.15	142.35	1:0.92

It is therefore apparent that, for many years, comparatively large quantities of storm water will be collected by the intercepting sewers and can be passed through the clarification works and discharged through the outfall sewer.

From table 41, it appears that the quantity of storm water which can be carried, were the sewers completed in 1910 would be 3.83 times the average flow of sewage when leakage is moderate; whereas in 1950, the quantity of storm water at such time would be nearly equal to the quantity of sewage. The dilution of sewage with storm water at the time of overflow would be increased or decreased as the quantity of sewage flowing at the time was less or greater than the average quantity.

The foregoing estimates of the quantity of sewage which will be produced have been made as the basis of design of sewers and disposal works. For calculations of operating conditions it may be desirable to use the annual average quantity of sewage which will probably be about 130 gallons per capita.

THE PEOPLE OF THE STATE OF NEW YORK,
COMPLAINANTS,

vs.

STATE OF NEW JERSEY ET AL.

HERE FOLLOW COMPLAINANTS' EXHIBITS RELATING TO DISSOLVED OXYGEN.

Shown in Nos. 159, 160, 161, 162, 163, 164, 165, 166, 167, 168, and 169.

JAMES D. MAHER,
Commissioner.

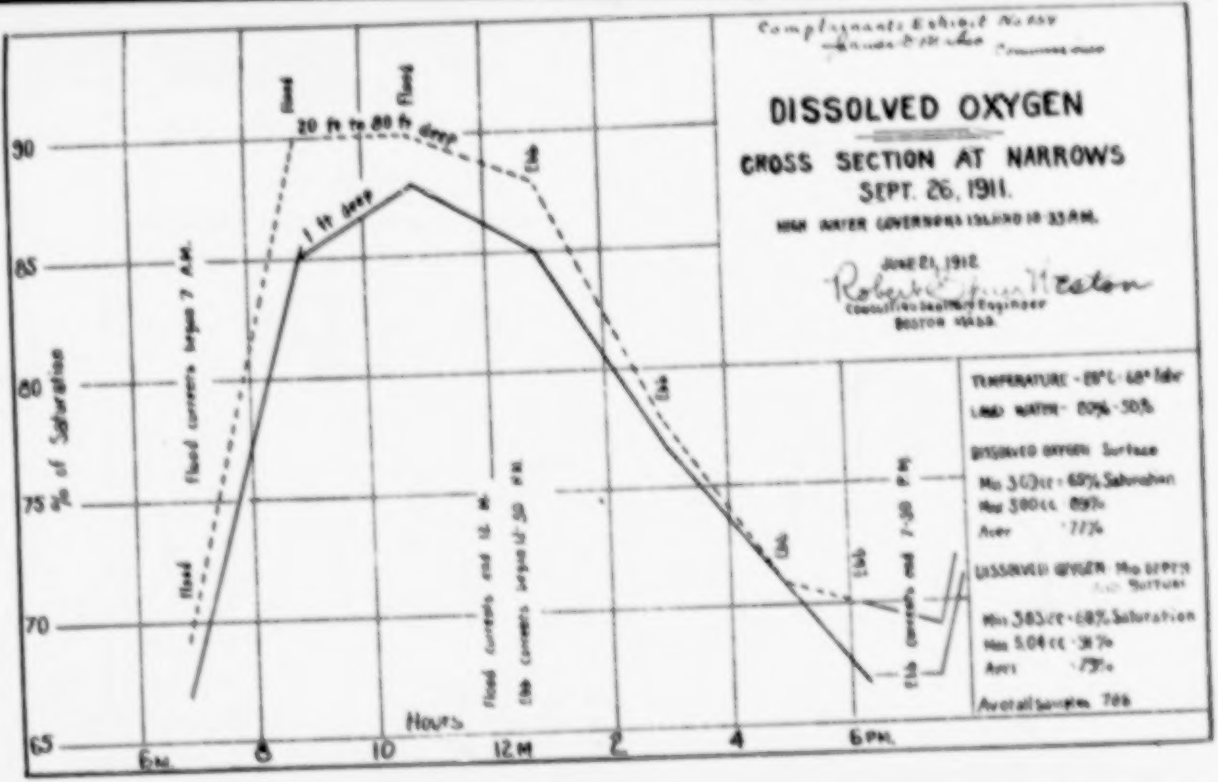

DISSOLVED OXYGEN
CROSS SECTION AT NARROWS
SEPT. 26, 1911.
HIGH WATER GOVERNORS ISLAND 10:33 A.M.
JUNE 21, 1912.
Robert Spurr Weston
Consulting Sanitary Engineer
BOSTON MASS.
TEMPERATURE - 20°C - 68° Fahr
LAND WATER - 80% - 30%
DISSOLVED OXYGEN: Surface
Min 3.03cc = 68% Saturation
Max 3.90cc 89%
Aver 77%
Avoral samples 786
% of Saturation
90
85
80
75
70
65
6 A.M.
8
10
12 M
2
4
6 P.M.
Hours
20 ft to 80 ft deep
1 ft deep
Flood
Ebb
Flood currents began 7 A.M.
Flood currents end 12 M.
Ebb currents began 12:30 P.M.
Ebb currents end 7:30 P.M.

Fig. 1

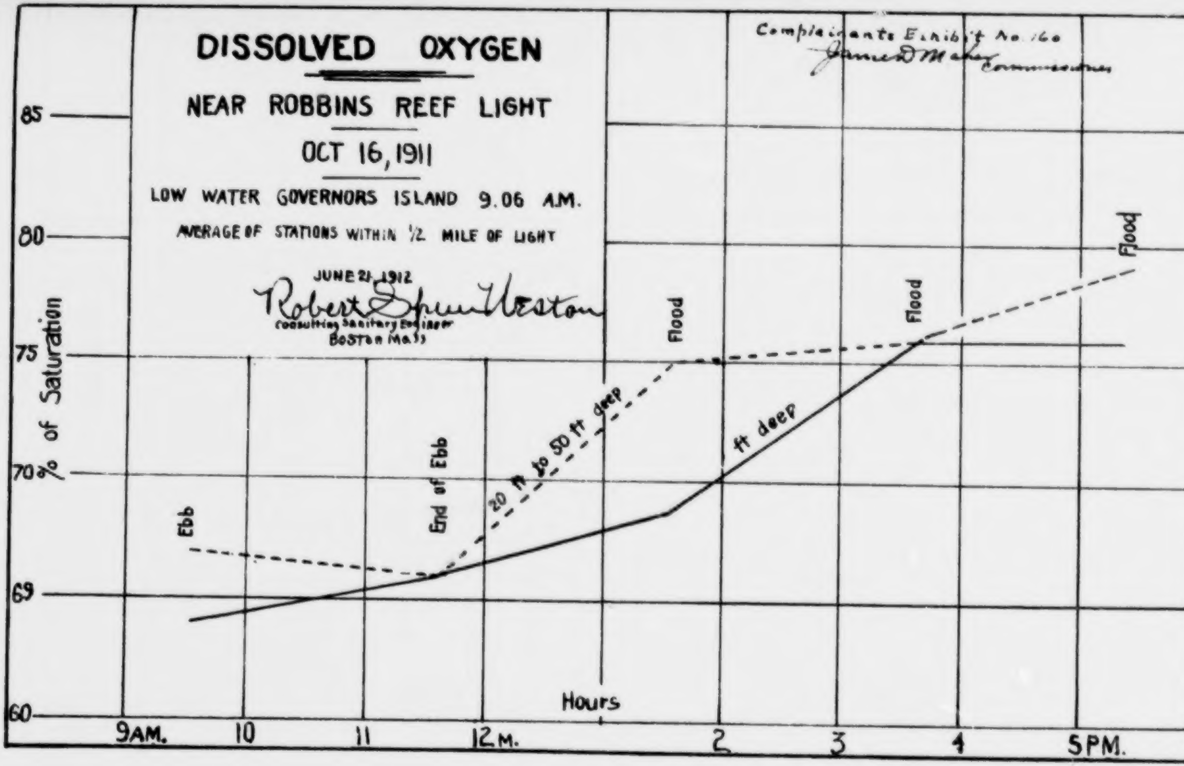

DISSOLVED OXYGEN
NEAR ROBBINS REEF LIGHT
OCT 16, 1911
LOW WATER GOVERNORS ISLAND 9.06 A.M.
AVERAGE OF STATIONS WITHIN 1/2 MILE OF LIGHT
JUNE 21, 1912
Robert Spurr Weston
Consulting Sanitary Engineer
Boston Mass
Complainants Exhibit No. 160
James D Maher
Commissioner
% of Saturation
85
80
75
70
69
60
Ebb
End of Ebb
20 ft to 50 ft deep
ft deep
Flood
Flood
Flood
Hours
9AM.
10
11
12M.
2
3
4
5PM.

Fig 2

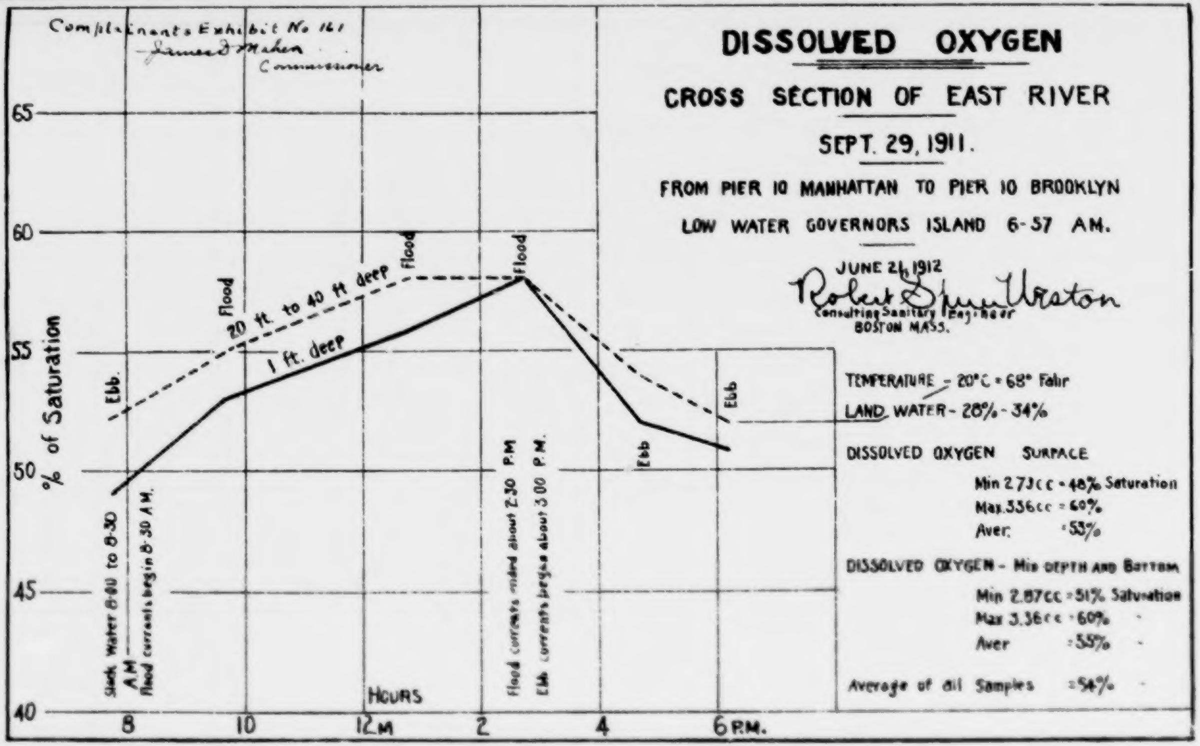
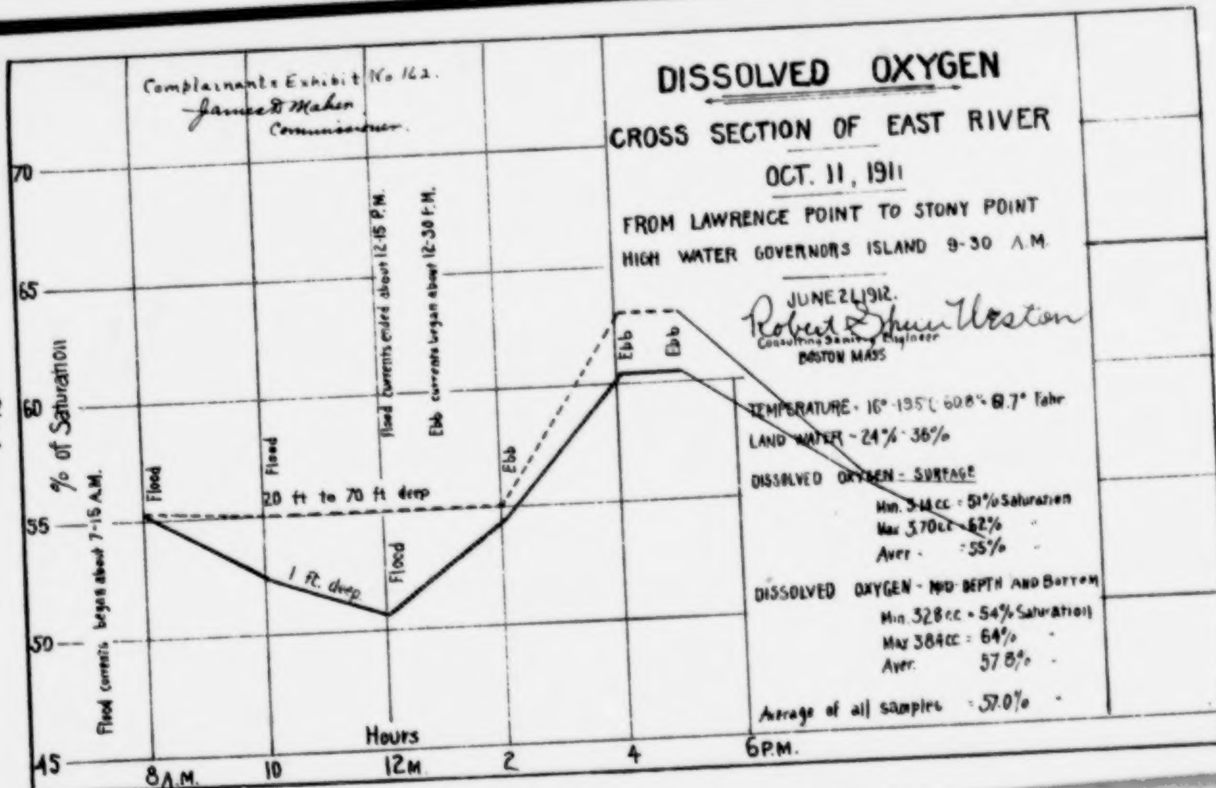
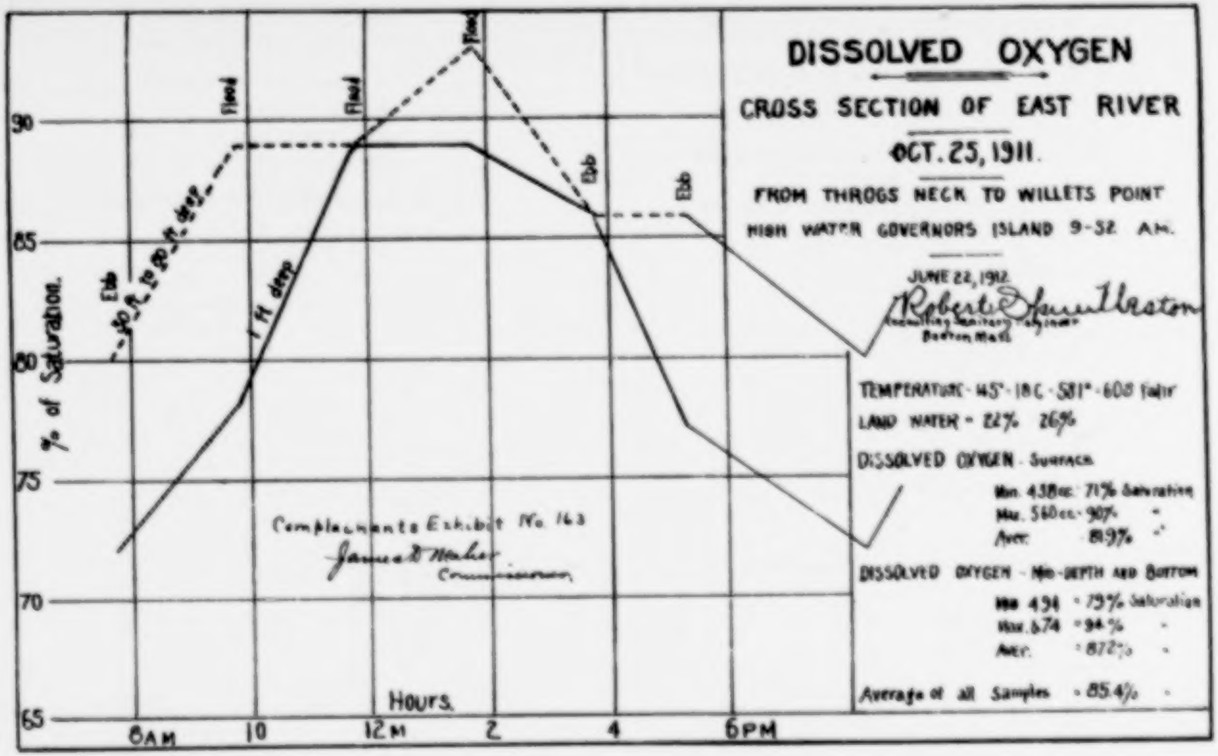

Complainants Exhibit No 161
James J Mahen
Commissioner
DISSOLVED OXYGEN
CROSS SECTION OF EAST RIVER
SEPT. 29, 1911.
FROM PIER 10 MANHATTAN TO PIER 10 BROOKLYN
LOW WATER GOVERNORS ISLAND 6-57 AM.
JUNE 24, 1912
Robert Spurr Weston
Consulting Sanitary Engineer
BOSTON MASS.
TEMPERATURE - 20°C = 68° Fahr
LAND WATER - 28% - 34%
DISSOLVED OXYGEN SURFACE
Min 2.73cc = 48% Saturation
Max. 3.36cc = 60%
Aver. = 53%
DISSOLVED OXYGEN - Mid DEPTH AND BOTTOM
Min 2.87cc = 51% Saturation
Max 3.36cc = 60%
Aver = 55%
Average of all Samples = 54%
% of Saturation
65
60
55
50
45
40
8
10
12M
2
4
6 P.M.
HOURS
20 ft. to 40 ft. deep
1 ft. deep
Ebb
Flood
Flood
Flood
Ebb
Ebb
Slack Water 8-00 to 8-30 A.M.
Flood currents begin 8-30 A.M.
Flood currents ended about 2-30 P.M.
Ebb currents began about 3.00 P.M.

Fig 3



Complainants Exhibit No 162.
James D. Maher
Commissioner
DISSOLVED OXYGEN
CROSS SECTION OF EAST RIVER
OCT. 11, 1911
FROM LAWRENCE POINT TO STONY POINT
HIGH WATER GOVERNORS ISLAND 9-30 A.M.
JUNE 21, 1912.
Robert Spurr Weston
Consulting Sanitary Engineer
BOSTON MASS
TEMPERATURE - 16°-15.5°C - 60.8°-59.7° Fahr
LAND WATER - 24% - 36%
DISSOLVED OXYGEN - SURFACE
Min. 3.11cc = 51% Saturation
Max 3.70cc = 62%
Aver. = 55%
DISSOLVED OXYGEN - MID-DEPTH AND BOTTOM
Min. 3.28cc = 54% Saturation
Max 3.84cc = 64%
Aver. 57.8%
Average of all samples = 57.0%
% of Saturation
70
65
60
55
50
45
Flood currents began about 7-15 A.M.
Flood currents ended about 12-15 P.M.
Ebb currents began about 12-30 P.M.
Flood
Flood
Flood
Ebb
Ebb
Ebb
20 ft to 70 ft deep
1 ft. deep
Hours
8 A.M.
10
12 M
2
4
6 P.M.

Fig. 4.



DISSOLVED OXYGEN
CROSS SECTION OF EAST RIVER
OCT. 25, 1911.
FROM THROGS NECK TO WILLETS POINT
HIGH WATER GOVERNORS ISLAND 9-32 AM.
JUNE 22, 1912.
Robert Spurr Weston
Boston Mass.
TEMPERATURE - 14.5° - 18 C - 58.1° - 60.8 Fahr
LAND WATER - 22% 26%
DISSOLVED OXYGEN - Surface
Min. 4.38cc. 71% Saturation
Max. 5.60cc. 90%
Aver. 81.9%
DISSOLVED OXYGEN - Mid-depth and Bottom
Min 4.34 - 79% Saturation
Max. 6.74 - 94%
Aver. - 87.2%
Average of all Samples - 85.4%
Complainants Exhibit No. 163
James D. Maher
Commissioner
% of Saturation.
90
85
80
75
70
65
Hours.
8 AM
10
12 M
2
4
6 PM
Flood
Flood
Flood
Ebb
Ebb
Ebb
1 ft deep
20 ft. to 30 ft. deep

Fig. 5.

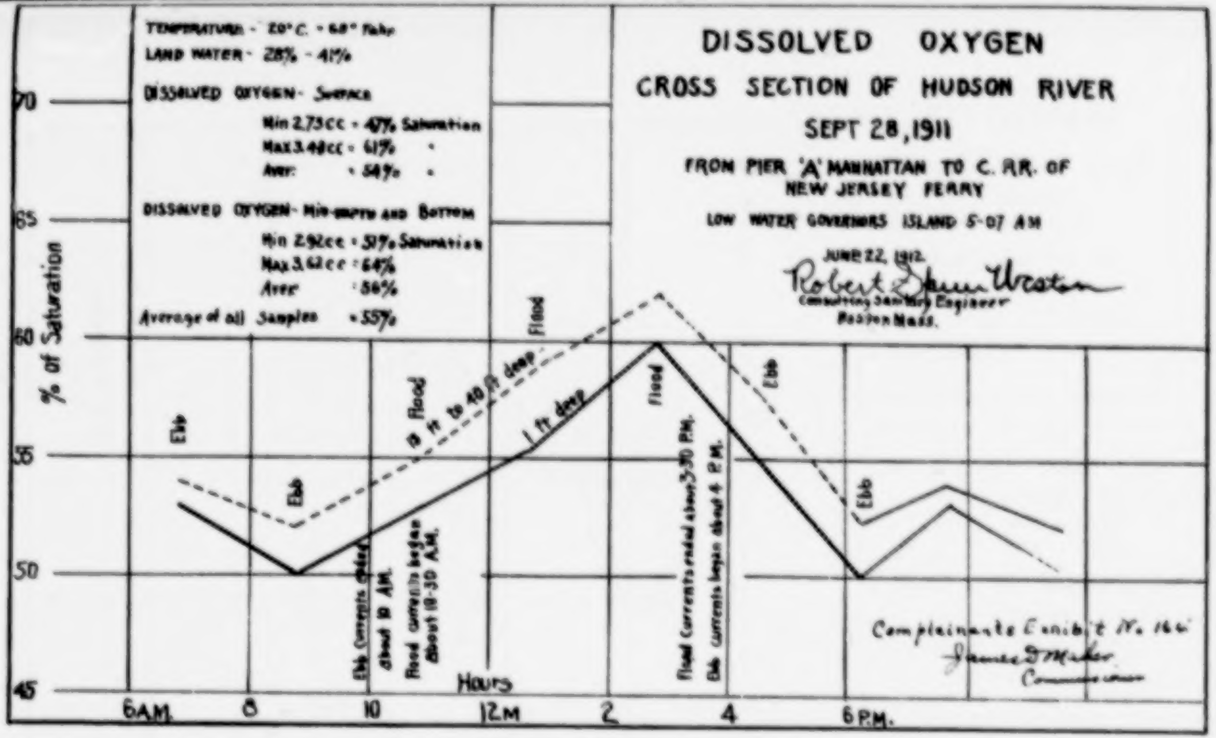

DISSOLVED OXYGEN
CROSS SECTION OF HUDSON RIVER
SEPT 28, 1911
FROM PIER 'A' MANHATTAN TO C. RR. OF NEW JERSEY FERRY
LOW WATER GOVERNORS ISLAND 5-07 AM
JUNE 22, 1912.
Robert Spurr Weston
Consulting Sanitary Engineer
Boston Mass.
TEMPERATURE - 20° C. - 68° Fahr
LAND WATER - 28% - 41%
DISSOLVED OXYGEN - Surface
Min 2.73cc = 47% Saturation
Max 3.48cc = 61% "
Aver. = 54% "
DISSOLVED OXYGEN - Mid-depth and Bottom
Min 2.92cc = 51% Saturation
Max 3.62cc = 64%
Aver = 56%
Average of all Samples = 55%
% of Saturation
70
65
60
55
50
45
Hours
6AM.
8
10
12M
2
4
6P.M.
Ebb
Flood
Ebb Currents ended about 10 AM.
Flood currents began about 10-30 A.M.
1 ft deep
13 ft to 40 ft deep
Flood Currents ended about 3:30 P.M.
Ebb currents began about 4 P.M.
Complainants Exhibit No. 164
James D. Maher
Commissioner

Fig. 6

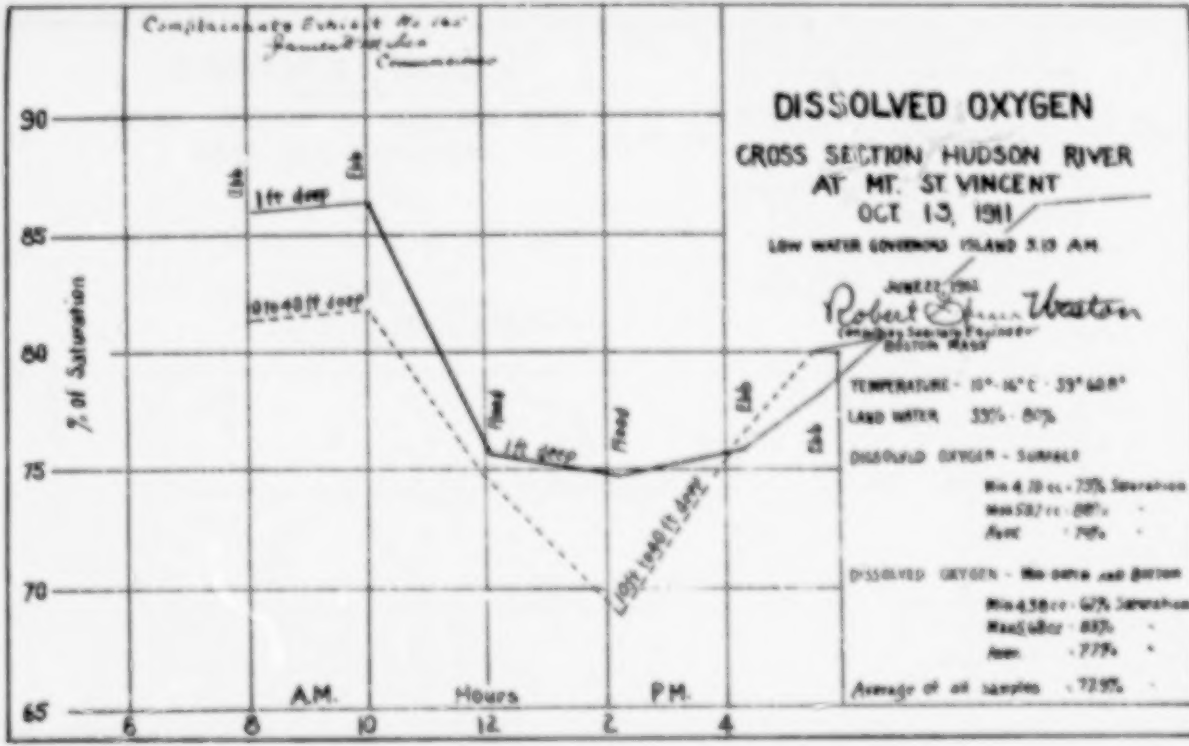

DISSOLVED OXYGEN
CROSS SECTION HUDSON RIVER
AT MT. ST VINCENT
OCT. 13, 1911
LOW WATER GOVERNORS ISLAND
% of Saturation
90
85
80
75
70
65
6
8
10
12
2
4
A.M.
Hours
P.M.
1 ft deep
Ebb
Flood
DISSOLVED OXYGEN - SURFACE
DISSOLVED OXYGEN
Average of all samples

Fig 7

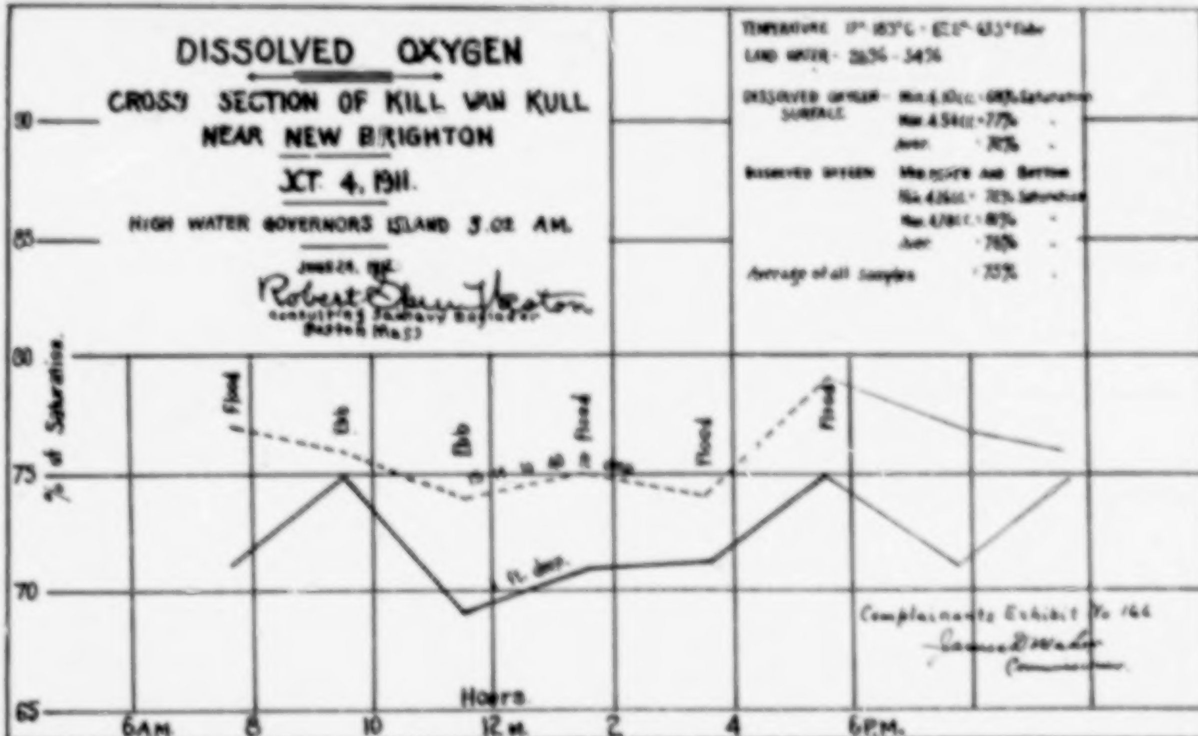

DISSOLVED OXYGEN
CROSS SECTION OF KILL VAN KULL
NEAR NEW BRIGHTON
HIGH WATER GOVERNORS ISLAND 5.02 A.M.
Robert Spurr Weston
Consulting Sanitary Engineer
Boston Mass
Average of all samples
% of Saturation
90
85
80
75
70
65
Flood
Ebb
Ebb
Flood
Flood
Flood
Hours
6AM
8
10
12M
2
4
6P.M.
Complainants Exhibit No 166

Fig.8.

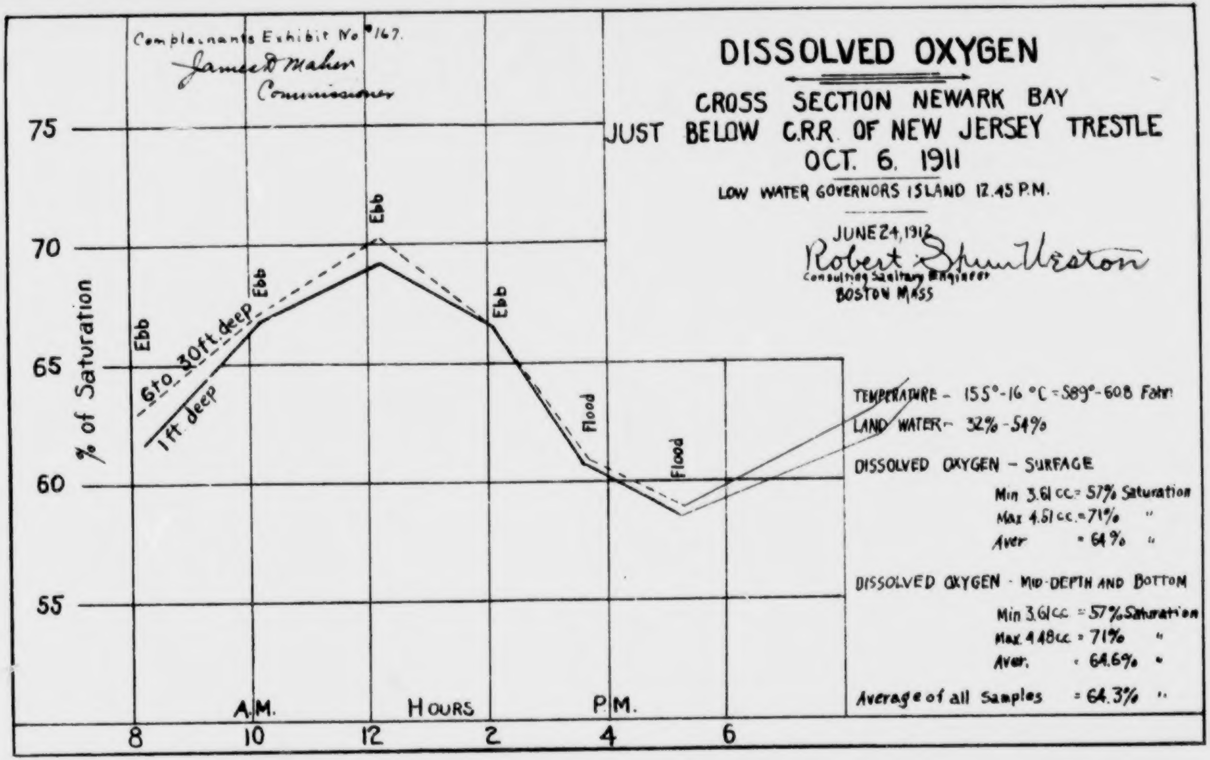

DISSOLVED OXYGEN
CROSS SECTION NEWARK BAY
JUST BELOW C.R.R. OF NEW JERSEY TRESTLE
OCT. 6. 1911
LOW WATER GOVERNORS ISLAND 12.45 P.M.
JUNE 24, 1912
Robert Spurr Weston
Consulting Sanitary Engineer
BOSTON MASS
Complainants Exhibit No. 167.
James D. Maher
Commissioner
TEMPERATURE - 15.5°-16 °C = 58.9°-60.8 Fahr.
LAND WATER - 32% - 54%
DISSOLVED OXYGEN - SURFACE
Min 3.61 cc = 57% Saturation
Max 4.51 cc = 71% "
Aver = 64% "
DISSOLVED OXYGEN - MID-DEPTH AND BOTTOM
Min 3.61 cc = 57% Saturation
Max 4.48 cc = 71% "
Aver. = 64.6% "
Average of all Samples = 64.3% "
% of Saturation
75
70
65
60
55
Ebb
Ebb
Ebb
Ebb
Flood
Flood
6 to 30 ft. deep
1 ft. deep
A.M.
Hours
P.M.
8
10
12
2
4
6

Fig. 9.

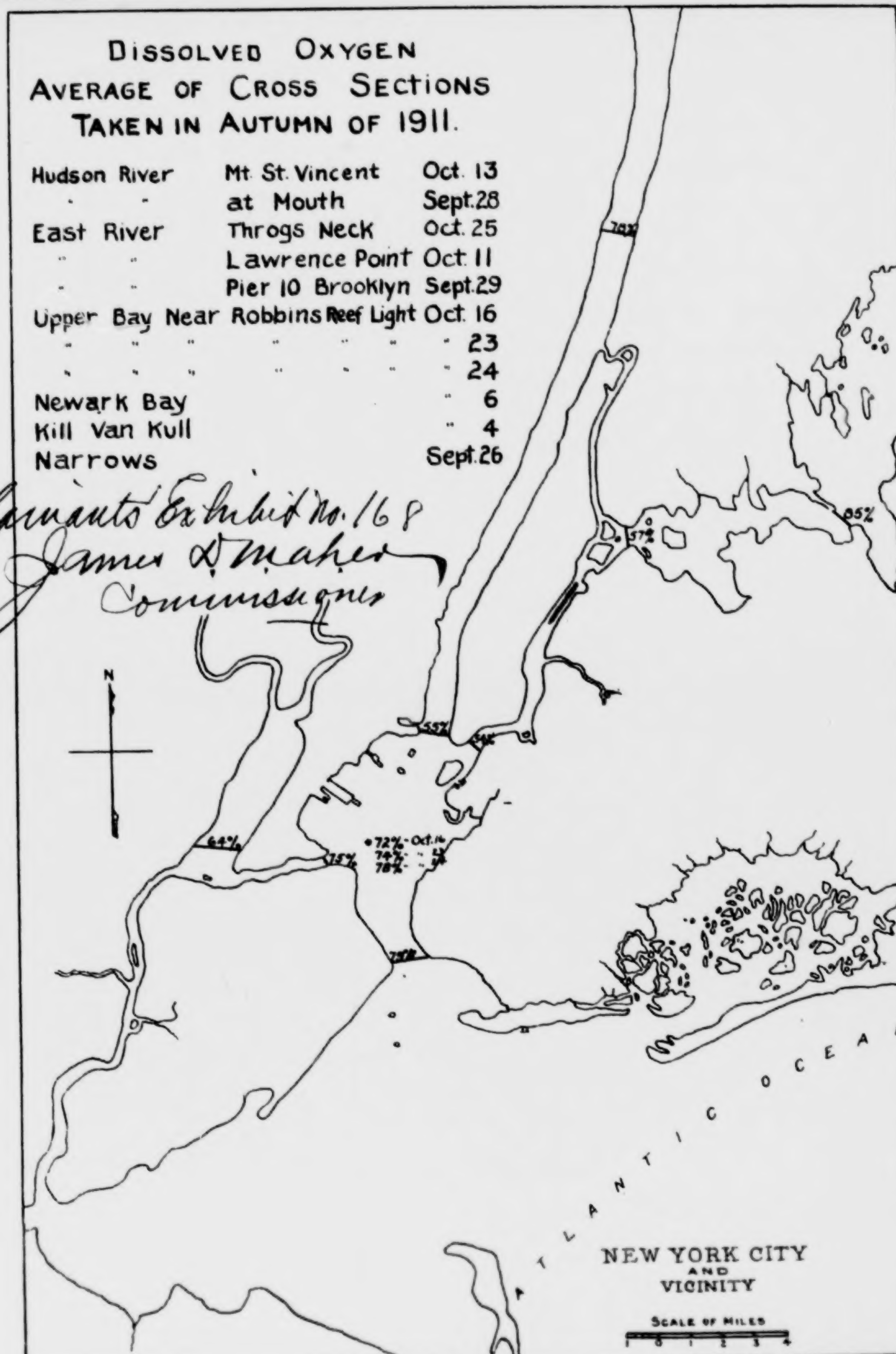
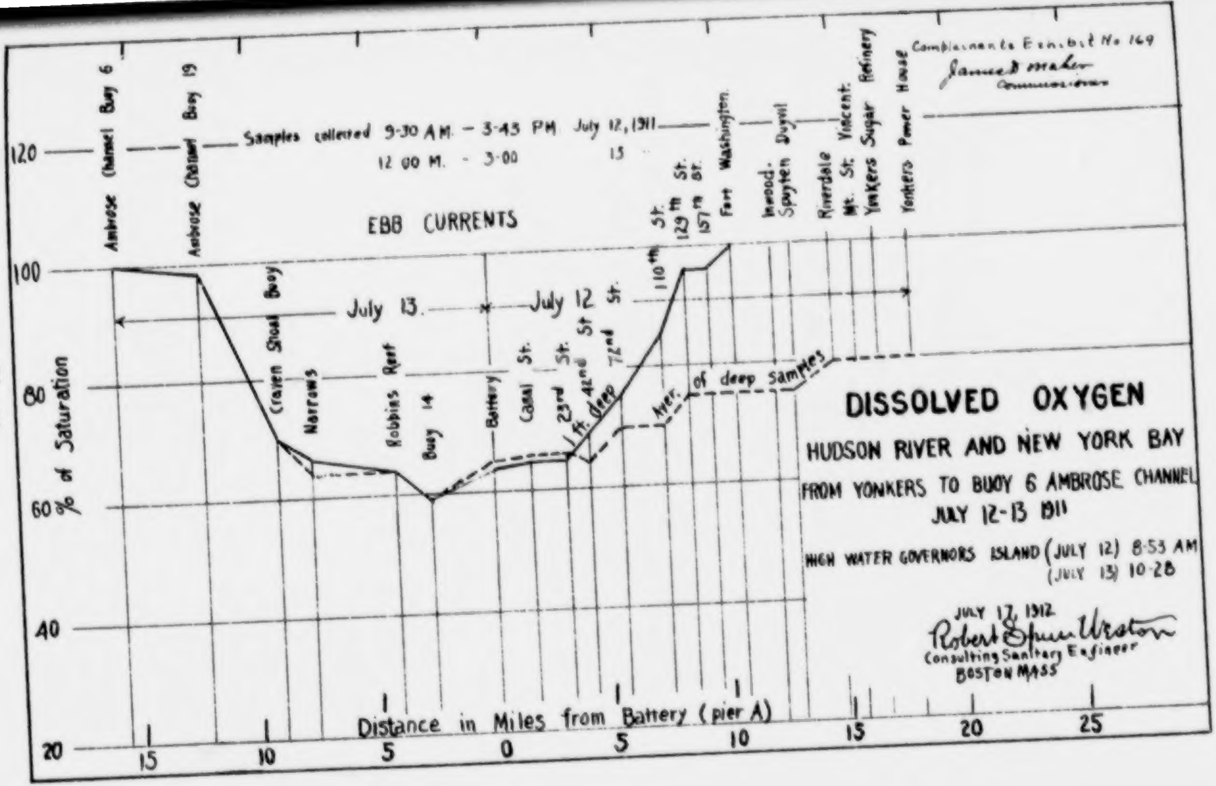


Fig. 10

Complainants' Exhibit No. 168
James D. Maher
Commissioner



Complainants Exhibit No 169
James D. Maher
Commissioner
Samples collected 9-30 A.M. - 3-43 P.M. July 12, 1911
12 00 M. - 3-00 13
EBB CURRENTS
Ambrose Channel Buoy 6
Ambrose Channel Buoy 19
Craven Shoal Buoy
Narrows
Robbins Reef
Buoy 14
Battery
Canal St.
23rd St.
42nd St.
72nd St.
110th St.
129th St.
157th St.
Fort Washington
Inwood-Spuyten Duyvil
Riverdale
Mt. St. Vincent
Yonkers Sugar Refinery
Yonkers Power House
July 13.
July 12
1 ft. deep
Aver. of deep samples
% of Saturation
120
100
80
60
40
20
Distance in Miles from Battery (pier A)
15
10
5
0
5
10
15
20
25
DISSOLVED OXYGEN
HUDSON RIVER AND NEW YORK BAY
FROM YONKERS TO BUOY 6 AMBROSE CHANNEL
JULY 12-13 1911
HIGH WATER GOVERNORS ISLAND (JULY 12) 8-53 AM
(JULY 13) 10-28
JULY 17, 1912
Robert Spurr Weston
Consulting Sanitary Engineer
BOSTON MASS

Fig. 11.

THE PEOPLE OF THE STATE OF NEW YORK,
COMPLAINANTS,

vs.

STATE OF NEW JERSEY ET AL.

HERE FOLLOW COMPLAINANTS' EXHIBITS Nos. 172, 173, 174, and 175.

Showing Results of Examination of Mud.

JAMES D. MAHER,
Commissioner.

Submitted by Olin H. Landreth
Sept 10.1912 — 2a

Pl Ex Complainants Exhibit No. 172
James D. Maher
Commissioner

SUMMARY OF RESULTS OF EXAMINATION OF MUD DEPOSITS, MADE BY THE METROPOLITAN SEWERAGE COMMISSION SUBSEQUENT TO JAN. 1, 1908.
PREPARED BY OLIN H. LANDRETH

TABLE I June, 1912

C O L O R

District or Locality	No. of Sample Examined	Black	Gray	Brown	Yellow	Blue	White
1. Hudson River	115	42	46	21	3	1	
2. East River	55	39	14	2			
3. Harlem River	7	5	2				
4. Upper Bay	207	100	94	13			
5. Lower Bay	103	20	29	51			3
6. Newark Bay and Passaic River	111	50	56			5	
7. The Kills	28	22	5	1			
8. Jamaica and Gravesend Bays	21	13	8				
9. L. I. Sound, Hempstead, Pt. Chester, Pelham Bays	52	11	30	10	1		
0. Gowanus Bay, Newtown Creek	7	7					
1. Raritan Bay, Cheesequake Creek	6	6					
2. Atlantic Ocean	6			2	4		
3. The Narrows	9	4	3	2			
T o t a l s	727	319	289	102	8	6	3

Complainants Ex hibit No. 174
James L. Maher
Commissioner

TABLE III.

C O N S I S T E N C Y

District of Locality	No. Samples	Sludge	Mud	Ooze	Clay	Sand	Gravel	Sub Soil
1. Hudson River	131	3	35		60	8	12	18
2. East River	78	34	15		22	4	2	1
3. Harlem River	7		7					
4. Upper Bay	655	150	45	2	236	140	14	65
5. Lower Bay	111		32		3	73	5	
6. Newark Bay, Passaic River	152	9	46		68	27	2	3
7. The Kills	48		32		1	10	5	
8. Jamaica and Gravesend Bays	27	2			17	6	2	
9. L. I. Sound, Hempstead, Pt. Chester, Pelham Bays	60	1	7		41	9	1	1
10. Gowanus Bay, Newtown Creek	7		5				1	
11. Raritan Bay, Cheesequake Creek	16		4		11		1	
12. Atlantic Ocean	8					2		
13. The Narrows	37	6			10	13	3	5
T o t a l s	1331	210	225	2	265	289	46	93

(Note:- The fact that the total number of samples examined (viz., 1331) exceeds the whole number of dredging is explained by the fact that in many cases a sample contained more than one substance.)

Complainants' Exhibit No. 175
James [illegible]
Commissioner

TABLE IV. P O L L U T I O N

District or Locality	No. Samples	Polluted	Unpolluted	Doubtful
1. Hudson River	110	39	57	14
2. East River	61	56	4	1
3. Harlem River	7	7		
4. Upper Bay	499	202	130	87
5. Lower Bay		26	62	12
6. Newark Bay, Passaic River	133	65	52	6
7. The Kills	45	22	17	6
8. Jamaica and Gravesend Bays	28	12	7	3
9. L. I. Sound, Hempstead, Pt. Chester, Pelham Bays		10	47	2
10. Gowanus Bay, Newtown Creek	7	7		
11. Raritan Bay, Cheesequake Creek	7		2	5
12. Atlantic Ocean	6		6	
13. The Narrows	23	19	1	5
T o t a l s	1069	565	365	139

THE PEOPLE OF THE STATE OF NEW YORK,
COMPLAINANTS,

VS.

STATE OF NEW JERSEY ET AL.

HERE FOLLOWS COMPLAINANTS' EXHIBIT No. 176.

Showing Results in Thames Dredging.

JAMES D. MAHER,
Commissioner.

17 Complainant Exhibit No. 176
James D. Maher
Commissioner.

T H A M E S D R E D G I N G S

Date of Collection (1906)	No.	Where Sample was Collected	Percentage Loss on Ignition #	5 Percentage of Nitrogen #	Probable Percentage of Sewage Sludge #	R e m a r k s	Loss of Dissolved Oxygen caused by the sample in Tap Water saturated with Air at 80 degrees F. — Weight of Mud per Litre. Wet	Dry	Hours of Contact	Dissolved Oxygen per Litre — Originally Present	After Period of Contact	Actual Loss	Percentage of Loss	
July 17	1	Barge House, North Woolwich	3.48	0.048	1.3	Coarse grey sand, showing a few black patches on keeping; odour like paraffin	---	---	---	----	----	----	----	
						Contained coal and cinders. On igniting scarcely blackened and no visible vapours	---	---	---	----	----	----	----	
"	2	Barking, near Outfall, North Side of Channel	11.69	0.388	13.9	Almost black mud; odour tarry; dried to a hard, grey cake, difficult to powder	12.5	4.38	3	5.77	1.74	4.03	69.8	2
						On igniting blackened and emitted odour with slight visible vapour	"	"	6	5.77	0.42	5.35	92.7	
"	3	Crossness, Half-way Reach, below Outfall	7.01	0.195	6.7	Almost black mud; odour tarry, dried to grey cake which powdered easily	12.5	3.32	3	5.77	3.27	2.50	43.5	3
						On igniting blackened and emitted odour but no visible vapour	"	"	8	5.77	1.35	4.42	76.6	
June 18	4	Greenhithe, North of Mid-Channel	11.76	0.382	13.7	Dark grey to black mud; no special odour dried to grey cake, difficult to powder	12.5	3.59	3	5.77	2.16	3.61	62.6	4
						On ignition blackened and emitted vapours with distinct odour	"	"	6	5.77	1.11	4.66	80.8	
"	5	Mucking, South of Mid-Channel	1.43	0.015	0.1	Coarse grey sand, showing a few black patches on keeping	----	----	-	----	----	----	----	
						On igniting only slight darkening and no visible vapour	----	----	-	----	----	----	----	
"	6	Chapman Light	1.34	0.015	0.1	Coarse grey sand, with some pebbles and shells. On igniting behaved like the Mucking sample	----	----	-	----	----	----	----	

On dry samples (see pp. 225-226).

1 COMPLAINANTS' EXHIBIT NO. 177. James D. Maher, Commissioner.

In the Supreme Court of the United States, October Term, 1912

No. 5, Original.

THE UNITED STATES OF AMERICA, Complainant,
vs.
THE PEOPLE OF THE STATE OF NEW YORK and JOHN E. ANDRUS et al.

Motion to Dismiss Bill Without Prejudice.

Now comes the Solicitor General on behalf of the complainant in the above-entitled case, and filing herewith a stipulation between the parties by which a settlement of the questions involved has been made, which settlement provides in paragraph seven (7) that said stipulation shall be filed in this Court and that the bill of complaint be dismissed without prejudice, moves the Court to dismiss said bill of complaint without prejudice.

(Signed) WM. MARSHALL BULLITT,
Solicitor General.

December 2, 1912.

2 In the Supreme Court of the United States.

In Equity.

THE UNITED STATES OF AMERICA, Complainant,
against
THE PEOPLE OF THE STATE OF NEW YORK and JOHN E. ANDRUS, William Archer, and John J. Brown, as Commissioners of the Bronx Valley Sewer, Defendants.

Stipulation.

Two years before the Bronx Valley Sewer was completed to the margin of the Hudson River or in any way put into use, the United States instituted the above cause in order to prevent the further defilement of that stream by the discharge from said sewer. With full notice of the claims set up and relief asked therein, the Commissioners named as defendants caused the sewer to be constructed to a point beneath the waters of the river some 20 feet from the Eastern bank; and for a time they allowed sewage to be received into and discharged therefrom. Such use of the sewer was enjoined in a proceeding instituted in the Supreme Court of New York for the County of Westchester by the Leak & Watts Orphan House, &c., in June, 1911. The United States has continuously objected to the proposed sewer;

and at all times has refused to assent to the construction of the same beyond the bulkhead line unless and until adequate provision should be made for the purification of the effluent.

After this cause was instituted, the terms of office of Commissioners Andrus, Archer and Brown, terminated; and under the pro-
3 visions of Chapter 361, Laws of New York for 1911, the undersigned, Frank Jerome Hoyle, Henry C. Merritt and John L. Hayes, were appointed. The latter now constitute the full membership of the Bronx Valley Sewer Commission and may rightfully exercise all its powers.

In order to end the present controversy and to secure permission to complete the sewer beyond the bulkhead line as was originally contemplated, and with the desire on the part of the United States ultimately to bring about adequate purification of the Hudson River, the following stipulation and agreement has been entered into by and between the United States and Frank Jerome Hoyle, Henry C. Merritt and John L. Hayes, as members of the Bronx Valley Sewer Commission, acting in behalf of themselves and of their successors in interest and control:

First. The Bronx Valley Sewer Commissioners at once will begin the installation of a plant for the partial purification of the effluent of the Bronx Valley sewer system by screening and sedimentation with an efficiency sufficient to remove and which shall at all times remove from said effluent enough of its putrescible contents to purify the same to the extent of 10% upon an absolute putrescibility scale. This plant shall be completed and put into operation on or before the first day of May, 1913; and it or one not less efficient shall be kept in continuous operation producing at least the results above specified so long as the Bronx Valley sewer continues in use.

Second. At all times during the operation of the Bronx Valley sewer system, in addition to those specified in the paragraph immediately above, the requirements enumerated under the seven heads immediately following will be met either through the plant and installations above called for or through requisite additional arrangements:

(1) There will be absence in the Hudson River of suspended particles visible to the naked eye coming from the effluent of said sewer.

(2) There will be absence of deposits in the waters of the Hudson River coming from the effluent of said sewer which the Secre-
4 tary of War of the United States, exercising a reasonable discretion, may find objectionable.

(3) There will be absence in the waters of the Hudson River and its vicinity of any odor due to the putrefaction of organic matter contained in the effluent of said sewer which the Secretary of War, exercising a reasonable discretion, may find objectionable.

(4) There will be a practical absence on the surface of the Hudson River, at the dispersion area or elsewhere, of any grease or color due to the discharge of said sewage.

(5) There will be no public or private nuisance occasioned by the discharge from the said sewer.

(6) The effluent from said sewer shall not injuriously affect property of the United States situated in the Hudson River.

(7) There shall be excluded from the sewer all refuse matters of the classes forbidden by law to be discharged into the navigable waters of the United States.

Third. At any time subsequent to January 1st, 1917, or to the date when there shall be 50,000 persons contributing sewage to said sewer,—whichever date first arrives—the Secretary of War of the United States may designate a board of three men, which shall make inquiry into the pollution of the Hudson River by the presence therein of sewage, filth and refuse matter, and upon a view of the facts and circumstances thought to deserve consideration, this board shall determine and thereafter report to him what, if any, purification of the effluent of the Bronx Valley sewer, in addition to that specified in the foregoing sections of this stipulation and irrespective of what others in fact may be doing towards bringing about the end desired, ought to be required in order to impose upon said sewer, its managers and the territory served by it, the performance of their just, fair and equitable part of whatever may be necessary for the restoration and maintenance of the waters of the Hudson River to and in such degree of purity as will render them adequate for the support of the life of shad and other major fish.

After receiving the report of this board, the Secretary of War may, from time to time, direct such further degree of purification of the effluent of the Bronx sewer not in excess of the findings of the board as he may think proper; and within two years after receiving any such direction, the Bronx Sewer Commissioners or their successors in control shall cause the same to be brought up to the required standard.

The board of three appointed by the Secretary of War shall include one member designated by the Bronx Sewer Commissioners or their successors, provided he be named within thirty days after request therefor, and provided further that all expenses incident to his service shall be borne by those in whose behalf he is designated. A majority of the board may act and a report concurred in by two members shall be the report of the board.

Fourth. At all times hereafter, through such representatives as he may designate, the Secretary of War of the United States shall have full opportunity to inspect the construction of the proposed purification plant and the condition and working of the entire sewer system, in order to determine whether the terms and provisions hereof are being observed in all respects; and to this end the Commissioners will render such expert or other assistance as he may request. Said Secretary at all times shall have the right to decide whether such terms and provisions are being complied with; and upon notice from him that they are not, the Commissioners or their successors shall forthwith do whatever may be necessary in order to effect compliance herewith.

Fifth. Full compliance at all times with the terms and requirements of this stipulation shall be and remain the express condition of any permits issued by or on the part of the United States

for the construction and future maintenance and operation of the Bronx Valley sewer or any part thereof.

Sixth. This stipulation shall not become effective unless and until all such permits as may be requisite under the statutes of the United States for the construction, maintenance and opera-
6 tion of said sewer, according to the plans and specifications heretofore prepared, are actually obtained nor unless or until such permits are made conditional upon the compliance at all times with all the terms hereof.

Seventh. As soon as the permits contemplated in the section immediately preceding have been issued and this agreement, properly executed, has been filed in the office of the Clerk of the Supreme Court as a stipulation between the parties in the above-entitled cause, the United States will cause the bill of complaint to be dismissed, but without prejudice.

Eighth. Nothing herein contained shall hinder or interfere with the assertion or execution by the United States of their rights and powers granted by the Constitution or Statutes.

In witness whereof, this instrument has been duly executed in triplicate, being signed in the name and on behalf of the United States by the Attorney General and by all the members of the Bronx Valley Sewer Commission and being sealed also on behalf of said Bronx Valley Sewer Commission with its seal attested by its Secretary—all on the 17th day of July, 1912.

THE UNITED STATES OF AMERICA,
(Signed) By GEO. W. WICKERSHAM,
Attorney General.

[SEAL.] THE BRONX VALLEY SEWER COMMISSION,
(Signed) By FRANK JEROME HOYLE,
(Signed) JOHN L. HAYES,
(Signed) HENRY C. MERRITT.

Attest:

(Signed) JAMES J. SHAW, *Secretary.*

Endorsed: Supreme Court of the United States. The United States of America, complainant, against the People of the State of New York, and John E. Andrus, William Archer and John J. Brown, as Commissioners of the Bronx Valley Sewer, defendants. Stipulation. Supreme Court U. S., October Term, 1912. Term No. 5, Original. The United States of America, complainant, vs. The People of the State of New York et al. Motion and stipulation to dismiss bill of complaint. Filed December 2, 1912.

Exhibit 178

-HAVANA HARBOR-
HAVANA, CUBA.

"Limit of Area considered in Estimating Dilution."

c COMPLAINANTS' EXHIBIT No. 178. James D. Maher, Commissioner.

Report upon Observations of the Pollution of Harbors of the Atlantic Seaboard by Sub-committee of Sub-committee Number 17 of the Experts for the State of New York in re Passaic Valley Trunk Sewer Project.

(Here follows map of Havana harbor.)

1 Nicholas S. Hill, Jr., Consulting Engineer, 100 William Street, New York.

Telephone 2053 John.
Water Supply.
Sanitary and Water Waste Investigations.
Fire Protection.
Water Power Development.
Filtration.
Pumping Stations.
Sewage Disposal.
Testing Laboratories for Analysis of Water, Analysis of Sewage, Analysis of Alloys, Testing of Coal, Testing of Sand, Testing of Cement.

Dr. W. J. O'Sullivan, Asst. Corporation Counsel, Hall of Records, City.

DEAR SIR: We respectfully submit our report upon the pollution of the harbors of those cities visited by your Committee during the month of December 1911.

The descriptions of the cities which follow are purely of an introductory nature, and are purposely made as brief as possible, and contain but very little data with relation to population, sewage flow, and information of like character, as all of these data, as well as other data relating to our investigations, are contained in the tables and statistics which follow.

General Description of Cities and Harbors.

Havana.

The City of Havana, Cuba, is built upon a peninsula and in relation to the Gulf of Mexico and its harbor, is located practically as shown on the accompanying map.

The old city, covering an area of some 1,500 acres, is but little above sea level, but the newer city and suburbs, covering about 4,500 acres, are hilly and reach, at some points, an elevation
2 of 130 feet above mean tide. The population is 360,000.

The waters of the harbor have a tidal range of about one foot between high and low water. The entrance to the harbor is through a narrow channel about 1,200 feet wide and about one mile in length. The area of the harbor is approximately 15,000 acres, giving a tidal displacement of approximately 65,000 cubic feet.

At the present time a complete system of sanitary sewers is being constructed for the entire city, which, when completed, will collect the sewage of the city and discharge it into the Gulf of Mexico at a point 4,000 feet east of Moro Castle in 30 feet of water.

At the present time the lateral system has been almost completed, and the sewage of the city, and suburbs tributary to the harbor, discharges through these new sewers and some old sewers that have not yet been intercepted.

At the time of our inspection, therefore, the sewage of the population tributary to the harbor was being discharged through outfalls along the water front. The aggregate population thus discharging sewage was, according to the estimate obtained from the Obras Publicas, approximately 87,000. Of this population, some 40,000 were discharging sewage through sewers at scattered points along the water front facing the main harbor, and where the tidal dilution and dispersion were relatively great.

The remainder of the population connected with sewers, approximating 47,000 people, were discharging their sewage into the
3 section of the harbor known as Atares Bay, an arm of the harbor lying at its extreme southwestern limit. Matadero Creek, St. Nicholas Creek, Dulco Creek, and other small creeks, draining a considerable portion of the suburban area of the city, empty into Atares Bay, and sewers of large size discharge into these.

It was to this latter section of the harbor, where objectionable conditions were very marked, that our observations and studies were largely restricted.

The accompanying map shows the location of the city with relation to that part of the harbor which was under observation.

The chief data relating to Atares Bay, as well as to portions of other harbors observed by us, are given in Tables Nos. 1 and 2, which follow.

The map shows the limits of pronounced and obnoxious visual sewage pollution, and the less marked but plainly visible sewage pollution.

(Here follows map of Baltimore harbor, page 4.)

Exhibit 178

Limit of Area considered in Estimating Dilution.-
CONTRIBUTING SEWAGE TO NORTH WEST
BALTIMORE
GWYNNS
FALLS
JONES
AREA OF VISIBLE POLLUTION
NORTH WEST HARBOR
PATAPSCO RIVER
-BALTIMORE HARBOR-
BALTIMORE, MD.

5 Baltimore.

The City of Baltimore, Md., is situated at the mouth of the Patapsco River, which empties into Chesapeake Bay, 160 miles from the Atlantic Ocean.

The city covers an area of approximately 19,200 acres, of which about 9,600 acres are densely built up. Its elevation varies from high tide at the docks to about 450 feet above mean low tide in the suburbs. Its population is 558,000.

The present sewer system consists of a number of storm water drains, entering into Jones Falls, Gwynns Falls, and the North West Harbor.

The sanitary sewage from about fifty per cent of a population of 290,000, in the more densely built up portion of the city, is carried by these drains into Jones Falls and the North West Harbor, with the result that they have become little better than open sewers, or cess pools, excessively offensive to sight and smell. The remaining fifty per cent of the population in the denser portions of the city here considered, is served by privy vaults and cess pools. The small per cent of population in other parts of the city connected to sewers, drains into Gwynns Falls and the Patapsco River.

The city is at present constructing an extensive system of sanitary sewers, designed to remedy the exceedingly bad conditions now obtaining in the North West Harbor.

The portion of the harbor and tidal area considered in this report in estimating sewage dilution is shown in blue on the accompanying map.

The tidal area of the North West Harbor is approximately 819 acres, and the tidal range is 1.2 feet. For details, see Appendix 1, Page 52.

(Here follows map of New York harbor, page 6.)

7 New York.

In this report, that portion of New York City and the surrounding communities is considered, the sewage from which empties into the Upper Bay. These communities are as follows:

Communities in the State of New Jersey Now Discharging Sewage ley Sewerage District.

Passaic County:

Paterson.
Manchester.
Prospect Park.
Hawthorne.
Aquackononk.
Passaic.

Bergen County:

Glen Rock.
Saddle River.
Midland.
Garfield.
Lodi Borough.
Hasbrouck Heights.
Woodridge.
Wallington.
Carlstadt.
East Rutherford.
Rutherford.
Union.
North Arlington.

Essex County:

Nutley.
Newark.
Belleville.
East Orange.
Bloomfield.
Glen Ridge.
Montclair.
Orange.

Hudson County:

Harrison.
East Newark.
Kearney.

Communities in the State of New Jersey, now Discharging Sewage Into the Hackensack River, Within the Metropolitan Sewerage District.

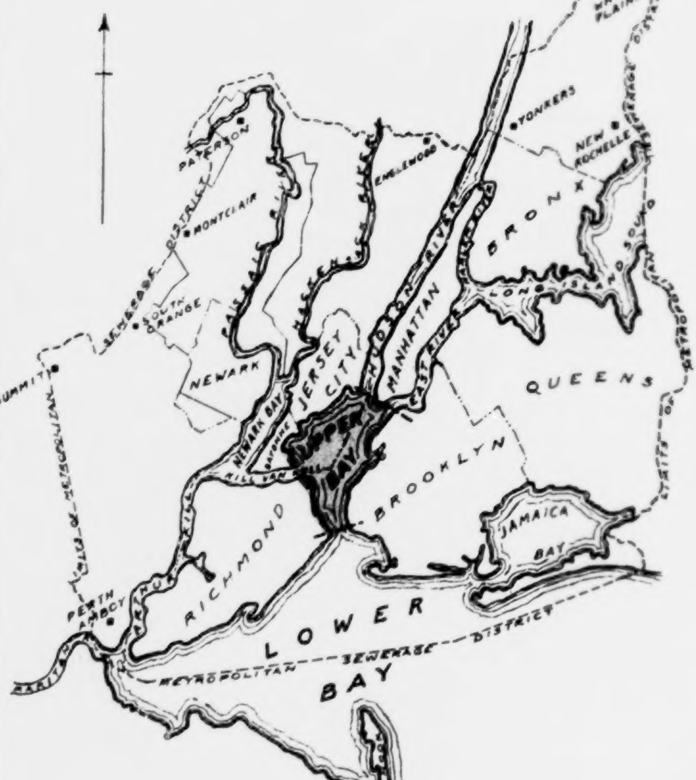
Hudson County:

Jersey City.
Kearney.
North Bergen.

Bergen County:

Fairfield.
Ridgefield.
Cliffside Park.
Palisade Park.
Maywood.
Lodi Township.
Hasbrouck Heights.
Little Ferry.

Exhibit 178



Limits of Area considered in Estimating Dilution.-

-NEW YORK HARBOR-
NEW YORK, N.Y.

8 Bergen County (continued):

Leonia.
Englewood.
Teaneck.
Bogota.
Overpeck.
New Barbadoes.
Woodridge.
Carlstadt.
East Rutherford.
Rutherford.
Union Township.
North Arlington.

Communities in the State of New Jersey Now Discharging Sewage Directly Into Upper New York Bay, the Kill von Kull, and Lower Hudson River.

Bayonne.
Jersey City.
Hoboken.
West Hoboken.
Union.
West New York.
Weehawken.
Guttenberg.
Woodcliff.
Edgewater.
Fort Lee.
Englewood Cliffs.

Communities in the State of New Jersey Now Discharging Sewage Into Newark Bay and the Arthur Kill, Excluding the Passaic and Hackensack Rivers.

Part of Newark.
" " Bayonne.
" " Jersey City.
Elizabeth.
Roselle Park.
Irvington.
South Orange.
West Orange.
Millburn.
Perth Amboy.
Summit.
South Orange Township.
Union Township.
Rahway.
Fanwood.
Cranford.
Garwood.
Roosevelt.
Woodbridge.

Communities in the State of New York Now Discharging Sewage Directly Into Upper New York Bay, the East River, the Harlem River, and the Lower Portion of the Hudson River.

Yonkers.
White Plains.
Scarsdale.
Tuckahoe.
Bronxville.
Mt. Vernon.
Bronx Borough.
Manhattan Borough.
Part of Brooklyn Borough.
" " Queens "
" " Richmond "

Communities in the State of New York Now Discharging Sewage Directly Into Newark Bay and the Arthur Kill.

Part of Richmond Borough.

9 It has been assumed that 80 per cent of the population within these communities contributes domestic sewage to the various drainage systems.

As it has been determined by the United States Coast and Geodetic Survey, and so reported by the Metropolitan Sewerage Commission, and the Central Committee of Experts for the State of New York that approximately 84 per cent of the water entering Newark Bay finds its way through Kill Van Kull into Upper New York Bay, the remaining 16 per cent going through Arthur Kill into Lower New York Bay, we have, for the purpose of estimating, assumed that but eighty-four per cent of the sewage, draining into the Passaic and Hackensack Rivers and into Newark Bay, reaches Upper New York Bay.

In other words, we have considered that all of the sewage which enters the Hudson and East Rivers, and Upper New York Bay, together with eighty-four per cent of the sewage reaching the Passaic, the Hackensack and Newark Bay, is contributary to Upper New York Bay. If the Passaic Valley Trunk Sewer is constructed, then, of course, one hundred per cent of the sewage from the Passaic Valley Sewerage District will be delivered directly into the Upper New York Bay in the vicinity of Robbins Reef Light.

The elevation of the district considered varies from high tide at the docks to about three hundred feet above mean tide in East Orange and White Plains.

The sanitary and combined sewers within this district discharge directly into the streams or bays tributary to the Upper New York Bay, or into the Bay itself. Many outlets are under piers at
10 the bulkhead line. These outlets are so numerous, however, that it is impossible to show them in the accompanying map, which displays the boundary of the district contributing sewage and the tidal areas considered in estimating dilution. For the purpose of estimating the dilution we have taken the total quantities of new sea and land water available in Upper New York Bay as explained in the Appendix.

(Here follows map of Potomac River at Washington, D. C., page 10½.)

Exhibit 178

- POTOMAC RIVER -
AT
WASHINGTON, D.C.

11 ## Washington.

The City of Washington is situated on the north bank of the Potomac River 156 miles from the entrance into Chesapeake Bay, and 185 miles from the Atlantic ocean. The Potomac at this point is quite a bold stream, draining an area of over 11,000 square miles.

The city has an area of approximately 6,400 acres tributary to the sewage system. It rises from the river level to an elevation of about 90 feet above mean tide. Its population is 343,000.

The city is almost completely sewered and is served with an extensive general system of combined sewers. The sanitary sewage of approximately 308,000 people is taken care of by the general sewerage system and is pumped to an outlet near the east bank of the Potomac River, three miles below the city, to which point the storm water drainage is also pumped.

The sewers in certain small districts discharge directly into the Potomac at several points along the water front.

The outlet of the general sewerage system consists of two 60 inch pipes, opening vertically at a depth of 28.7 feet below mean high tide, and at a distance of 750 and 800 feet respectively from the river bank. The location of these outlets is indicated by a red dot upon the accompanying map. The sewer outlet is carried well out into the main shipchannel where the currents in the river have the greatest velocity.

12 Washington is located at the head of tide water, the tidal range being 2.9 feet. The fresh water dilution is so great that the sewage may be considered to empty into a fresh water stream.

Notwithstanding the very slight difference in density of the sewage and river water, the vertical rise of the sewage was rapid, judging from the surface effects, at the time of our visit, and although the sewage was partially screened, the visual evidence of the sewage in the form of particles of feces, match sticks, paper, etc., were apparent for a mile or more north of the outlet. The observed sewage field is indicated on the accompanying map. The turbidity of the Potomac water at the time the observations were made was sufficient to materially lessen the visual effects which would result in clear water.

The observations herein reported were limited to a study of the outlet just described, and the estimated tidal dilution is considered to be the average annual daily fresh water flow of the Potomac River at this point.

(Here follows map of Tampa harbor, page 13.)

14

Tampa.

The City of Tampa, Florida, is situated at the northern extremity of Hillsboro Bay, the eastern arm of Tampa Bay on the west coast of Florida, and 35 miles from the Gulf of Mexico.

The main outlet of the sewer system is a horizontal pipe, six feet in diameter, opening at the edge of a dock near the mouth of the Hillsboro River and nine feet below mean tide. This outlet delivers the sewage of about 10,000 people of a total of 13,000 connected with sewers in the City of Tampa.

There are two other outlets emptying into the Hillsboro River, which serve approximately 3,000 people.

Our observations were confined practically to the main outlet.

The limits of the tidal area considered are shown on the accompanying map. This area is approximately 134 acres. The tidal range is two feet.

The conditions of the main outlet in Tampa were peculiarly interesting as they offered an excellent opportunity for observing the rapid rise of fresh water sewage in strongly saline waters. The salinity of the water near the point of the main outlet was 14,400 parts per million.

The sewage flowing from this outlet rose at once to the surface, boiling up above the surface of the surrounding water, forming a mushroom shaped mound, distributing sewage over an area ten feet in diameter, which floated down stream on the surface of the tide, spreading out in fan shape, as it progressed downstream.

15 For a distance of 100 feet below the outlet, the water showed a very marked sewage color, and had an offensive odor and marked discoloration, and more or less dissipated floating feces and sewage matter were noted at a distance of 750 feet below the outfall.

(Here follows map of Boston harbor, page 16.)

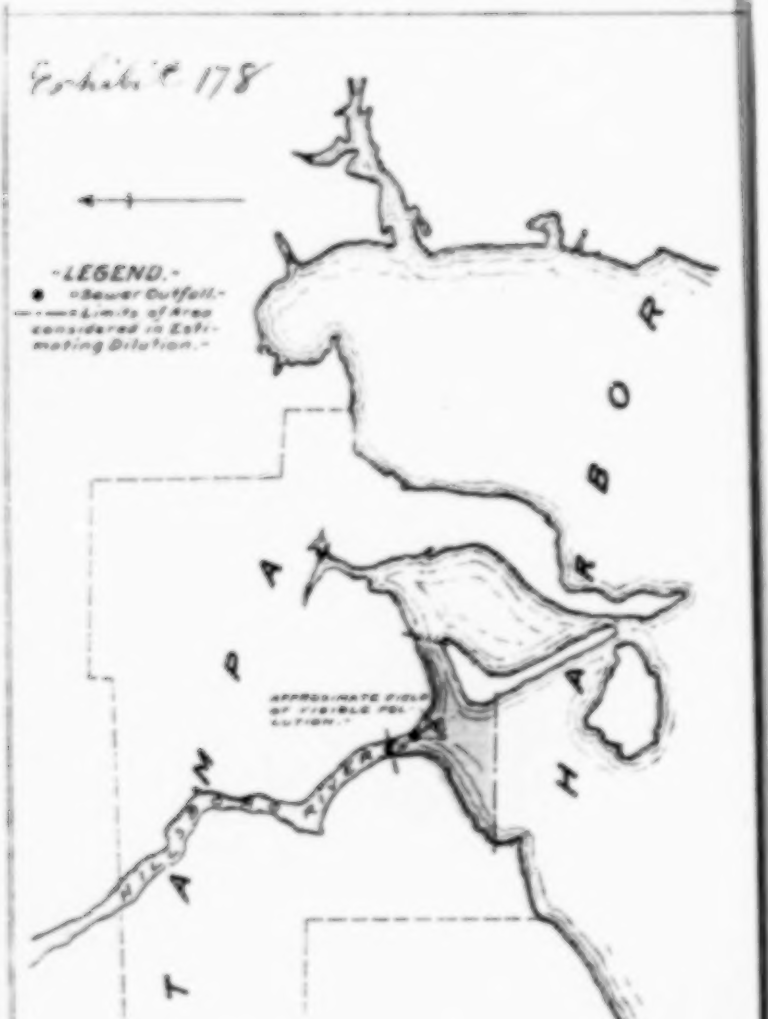

-LEGEND.-
-Sewer Outfall.-
-Limits of Area considered in Estimating Dilution.-
APPROXIMATE FIELD OF VISIBLE POLLUTION.-
TAMPA HARBOR
-TAMPA HARBOR-
TAMPA, FLA.

Exhibit 178

-BOSTON HARBOR-
BOSTON, MASS.

LEGEND.

● = Sewer Outfalls.-
— = Limits of Area considered in Estimating Dilution.-
= Approximate Field of Visible Pollution.

17 **Boston.**

The City of Boston, Mass., is situated at the mouth of the Charles River, at the head of Boston Harbor on the coast of Massachusetts.

The territory about Boston, considered in this report, comprises the "Boston Metropolitan Sewerage District" and the "Boston Main Drainage District," and has a total area of approximately 206 square miles. Its elevation varies between the tide water at Boston, and 500 feet above mean tide at the headwaters of the Charles River.

The sewage from the densely built up portion of Boston is collected by the sewers of the "Boston Main Drainage System," and is pumped to tanks on Moon Island, where it is stored until the tide is ebbing, when it is discharged into the harbor, producing a clearly marked area of greasy, sewage colored water. The sewage from the surrounding communities is collected by the sewers of the "Boston Metropolitan Sewerage District." This sewage is discharged into the harbor at Deer Island and Peddock's Island, as indicated on the accompanying map. This map displays also the tidal area considered in estimating sewage dilution and the limits of the "Boston Metropolitan Sewerage District" and the "Boston Main Drainage District." It also indicates the visual field of sewerage pollution as derived from the report of the Massachusetts State Board of Health for the year 1900.

Boston Harbor has been the subject of much study by the Massachusetts State Board of Health, a special report having been made thereon in 1900 by Mr. Goodnough as Chief Engineer.

18 Again, in 1905 Mr. Goodnough made a second report, as published in the Report of the Massachusetts State Board of Health for that year.

The facts which are given in this report are largely quoted from the data contained in the two reports of Mr. Goodnough and from the published reports of the Metropolitan Water and Sewerage Board for the years 1905 and 1910.

Your Committee did not visit Boston, but the facts as set forth have been collected for the purpose of comparing conditions in Boston with those in New York Harbor.

(Here follows map of Savannah River at Savannah, Ga., page 19.)

20 Savannah.

The City of Savannah, Georgia, is situated on the south bank of the Savannah River, 18 miles from the mouth.

That portion of the city tributary to the sewer system covers an area of 1,220 acres, and includes the densely populated sections. It is built upon low land, its highest point having an elevation of but 52 feet above mean low water in the river. One half of the area of the city has an average elevation of only 35 feet above mean tide.

There are 51 miles of sanitary sewers, emptying into the Savannah River at two points. The principal outlet is at Gordon's Wharf and is a 30-inch horizontal pipe ending at the wharf line and 13 feet below mean low water. These sewers serve only about three-quarters of the population. The remainder use privy vaults and dry closets. At the present time, however, there is a movement on foot to extend the sewer system to the outlying districts.

An examination of the river at Savannah during flood tide on January 12, 1912, showed no visual evidence of sewage pollution, the river appearing generally clean, though turbid.

Of all the harbors visited by your Committee, Savannah afforded the best opportunity of studying the effects of turbidity upon the visual surface nuisance to be observed in the vicinity of sewer outfalls. It was plainly evident that high turbidity appreciably reduced visual effects, so much so that it was difficult to observe the sewage immediately at the outfall at high tide. The high turbidity of the water in the Savannah River, coupled with its low specific gravity, accounts for this condition.

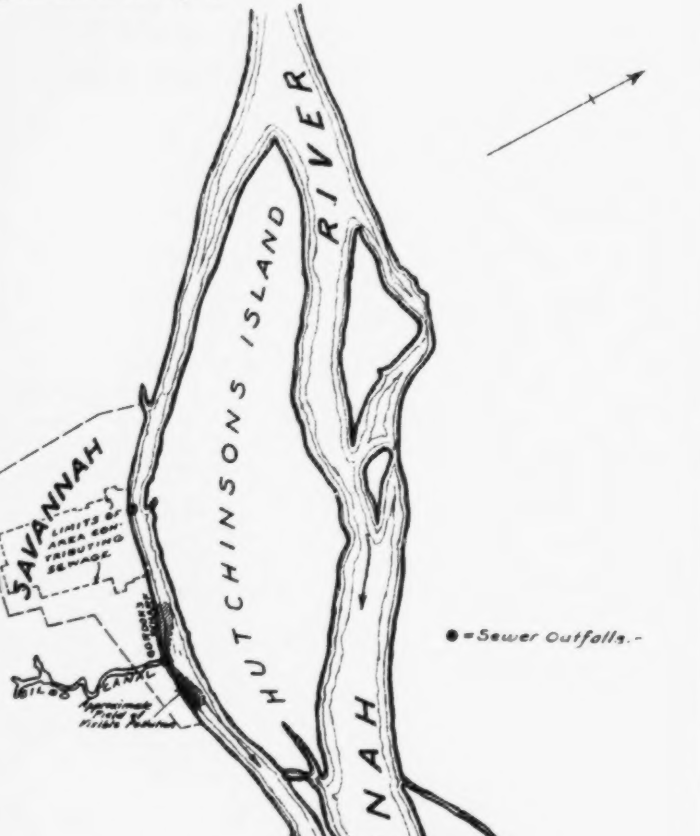
21 The salinity of the water here, as in Washington, is very low.

At slack tide, the sewage rises to the surface at a point 50 feet north of the pier line, and on ebb tide evidences of the sewage were observed for a distanc of 1,600 feet down stream from the outlet.

The owner of the boat from which these observations were made, as well as a fore man on the wharves, stated that under the piers, in summer, the stench of sewage was very noticeable for an appreciable distance each side of the sewage outlet.

The tidal velocity in this stream is very high at the center of the river, and, as has been observed, in the case of New York Harbor, the tidal velocity along the shore lines is very much reduced by the piles and other obstructions sustaining the piers. The result is that in Savannah, as in New York, the sewage flows in a line parallel with the axis of the river and hugs closely to the shore. Under these conditions, it is but natural that there should be a heavy deposition of suspended matter under the piers, and no doubt, if the Gordon Street outlet could be observed in warm weather, septic action of the bottom mud would be noticed for an appreciable distance each side of this outlet.

Exhibit 178



-SAVANNAH RIVER-
AT
SAVANNAH, GA.

The accompanying map shows the location of the sewer outlets.

Savannah, as in the case of Washington, was considered as having only that dilution produced by the fresh water flow of the river. The Savannah River drains an area of approximately 11,000 square miles above its sewer outlet.

(Here follows map of St. John's River at Jacksonville, Fla., page 22.)

23 Jacksonville.

Jacksonville, Florida, is situated on the north bank of the St. John's River at a bend 22 miles above its mouth. The St. John's drains an area of 8,143 square miles above Jacksonville.

The city is not closely built up, and covers a considerable area at an elevation of from 0 to 43 feet above the river.

There are sixty-seven miles of sewers, principally sanitary, leading to eight outfall sewers, as follows, reading from east to west on the accompanying map:

Fairfield Outfall.
Georgia Street.
Catherine "
Market "
Main "
Cedar "
Stonewall "
Osceola "

At the Fairfield outfall, the sewage is pumped out under head. To the others, the sewage flows by gravity to outfalls at a depth of from 4 to 20 feet below the water in the river and are horizontal with the exception of the Market Street and Stonewall Street sewers, which are turned down. In size, they range from 8 to 24 inches in diameter.

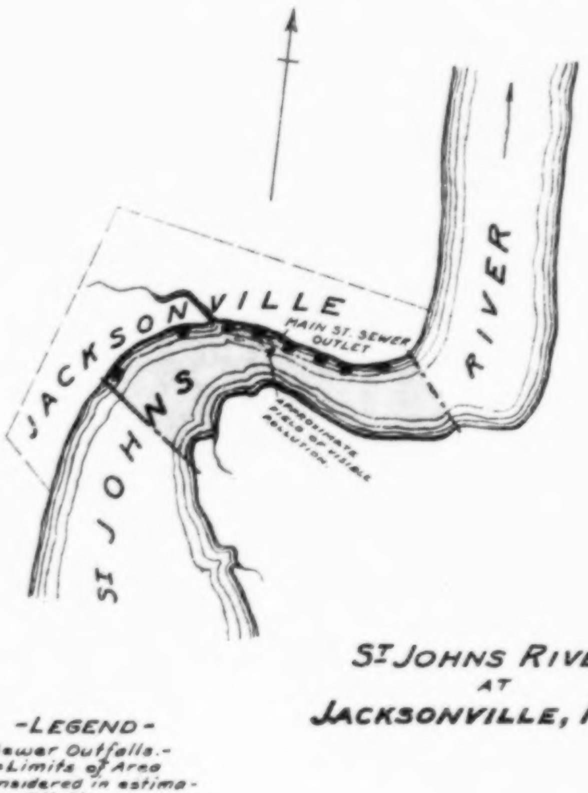
These sewers serve about one-half of the population, the remainder being provided with privy vaults or dry closets.

The position of these outlets is indicated at ebb tide by an area of discoloration of the river water, and at the Main Street outlet by noticeable boiling. At the Catherine Street outlet, which was located at the pier head, there was visible evidence of septic action in the bottom mud for an area one hundred foot square, to-
24 gether with a distinct sewage odor, though the temperature of the water at the time of inspection was but fifty-five degrees.

Our observations at Jacksonville were confined chiefly to the Main Street sewer, the largest and most important of the local sewers. This sewer discharges about three million gallons daily. It has a 24 inch horizontal outlet placed about 20 feet below mean tide. The sewage was plainly visible at the surface and the visible sewage field adjacent to this sewer is indicated on the accompanying map. The map also shows the limits of the tidal area considered in estimating the dilution at Jacksonville.

(Here follows map of Charleston harbor, page 25.)

Exhibit 178



S^T JOHNS RIVER
AT
JACKSONVILLE, FLA.

-LEGEND-

● = Sewer Outfalls.-

—·— = Limits of Area considered in estimating Dilution.-

-CHARLESTON HARBOR-
CHARLESTON, S.C.

-TABLE No. 1.-

-LAND WATER FLOW, TIDAL RANGE, TIDAL AREA CONSIDERED AND CHARACTER OF HARBOR WATERS.-

-City.-	Drainage Area Contributing Land Water. (Sq. Mi.)	Annual Rainfall. (Inches.)	Run Off (Per Cent of Rainfall.)	Fresh Water Flow. (Mi. Cu. Ft. in 12 hrs.)	Tidal Range (Ft.)	Tidal Area Considered (Acres.)	-Character of Harbor Waters.- Temperature of Water (Degrees F.)	Salinity.	Turbidity.	Dissolved Oxygen. (% Saturation)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Havana.	4.5	50.00	28.0%	0.2	1.0	175	75°F	18,500	20	94.9
Baltimore.	47.0	50.88	36.0 -	2.8	1.2	819	41 -	4,500	25	84.4
New York.	14,571.0			*1180.0	4.4	13,274		11,916		90.0
Washington.	11,043.0	36.86	39.0 -	500.0	2.9	0	42 -	6	75	97.0
Tampa.	602.0	53.73	40.0 -	41.2	2.0	134	65 -	14,400	40	90.0
Savannah.	11,100.0	50.00	42.2 -	143.0	7.0	0	50 -	150	100	90.0
Charleston.	1,622.0	48.73	40.0 -	103.0	2.7	3,900	54 -	17,000	18	91.0
Jacksonville.	8,143.0	53.75	20.0 -	556.0	3.5	1,842	54 -	3,300	19	88.0
Boston.	662.0	45.68	48.5 -	46.6	10.0	28,900				

* New Land Water available for Dilution; from "Brief Report on Tidal Actions in the Harbor of New York", by Mr. H. de B. Parsons.-

(Exhibit No. 178)

TABLE Nº 2.

POPULATION AND ESTIMATED VOLUME OF SEWAGE.

City	Population of City or Area Considered - 1940			Volume of Sewage				
	Total	Contributing Sewage	Per cent Contributing Sewage	Domestic & Mfg. Wastes from public sources per cap.	Mfg. Wastes from private sources per cap.	Infiltration per capita Gal. Daily	Total Sewage per capita Gal. Daily	Gross Sewage Millions of cubic feet per 12 hours
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Havana	360,000	47,000	13 %	125	0	50	175	0.55
New York - 1940	12,000,000	9,600,000	80 %	130	20	50	200	128.00
Baltimore	558,000	145,000	26 %	121	10	50	181	1.75
New York - 1910	6,000,000	4,800,000	80 %	113	10	50	173	55.40
Washington	343,000	308,700	90 %	—	—	—	218	4.50
Tampa	37,382	13,360	36 %	125	0	50	175	0.16
Boston	1,371,000	1,165,000	85 %	—	—	—	175	13.60
Savannah	67,000	49,000	73 %	153	0	50	203	0.66
Jacksonville	60,000	35,000	58 %	83	0	50	133	0.31
Charleston	59,000	19,700	33 %	87	0	50	137	0.18

26 ## Charleston.

The City of Charleston, South Carolina, is situated on the southern point of a low peninsula washed on the east by the Cooper River, and on the west by the Ashley River. To the south, Charleston Harbor extends 6 miles to the Atlantic Ocean.

The area of the built-up portion of the city is 7,680 acres, and its average elevation is about 15 feet above mean tide.

The sewer system at the present time consists chiefly of certain tidal drains to which connections have been made by a small number of houses. In the southern end of the city there are about five or six miles of sanitary sewers, which are now in use. The city is at present, however, engaged in the construction of a general system of sanitary sewers.

The total number of houses in Charleston is approximately from eight to ten thousand, and the number of privy vaults, or dry closets, five to seven thousand, so that possibly not more than three thousand houses are connected up with existing sewers and drains.

The sewer system will comprise some fifty miles of sanitary sewers, which will empty into the Ashley and Cooper Rivers along the water front.

At the time of our inspections no evidence of pollution was observed in the harbor, except local nuisance in the immediate vicinity of the outlets.

The tidal drain leading into Gadsden Creek was closed at the time of our visit. This creek drains a large marsh, and in going
through the marsh in a row boat, the visual evidences of
27 sewage pollution were very marked and there was an appreciable odor of sewage everywhere prevalent. No doubt, this marsh is a source of considerable nuisance in warm weather.

This condition offers a very excellent illustration of the broad local nuisance produced by emptying sewage, even in small amounts, into shallow waters exposed to the full effects of the sun, a condition which was brought prominently to attention on the old Potomac flats prior to the reclamation of the island now forming Potomac Park, and the construction of the main sewer outfall at its present location three miles below Washington. Formerly, the sewage of Washington was carried into the Potomac River at various points along the shore front, and on the flood tide would spread upon the flats where the suspended matter was quickly deposited. With the receding tide, this organic matter was exposed to the influence of the sun, the result being that the foul smelling odors carried by southerly winds were plainly marked at distances as far north as the White House.

The accompanying map shows the location of sewer outlets and the area considered in estimating dilution.

(Here follow Table No. 1 and Table No. 2, pages 28 *a* and 28 *b*.)

29 Relative Effects of Pollution in Different Harbors.

Basic Data.

Tables Nos. 1 and 2 give in condensed form the basic data from which Table No. 3, which follows, was compiled. The basic data for, and explanation of Table No. 1 will be found in Appendix No. 1 and similarly for Table No. 2 in Appendix 2.

Table No. 3 shows the relative degree of pollution in the various harbors considered in the report, the resulting dilution, the per cent of saturation of dissolved oxygen, and the putrescibility of the harbor mud, together with an estimate of the number of tons of wet sewage sludge per million cubic feet of total water (fresh and salt) available for dilution.

Averages Used.

For the purpose of avoiding complication, and in order to obtain a clear conception for a broad general estimate of the permissible pollution of harbors, figures for average tidal range, average rainfall and runoff, and average sewage flow have been used throughout.

Dilution.

The sea water available for dilution (Col. 5, Table 3) in Upper New York Bay is the new sea water which does not return on the next succeeding tide as computed by Mr. H. de B. Parsons in his brief report on "The Tidal Actions in the Harbor of New York." The figures given by Mr. Parsons are substantially those used by the Metropolitan Sewerage Commission. To this was added the new land, or fresh water, as estimated by the same authorities, and approved by the Central Committee Experts.

(Here follows Table No. 3, page 29½.)

([illegible])

TABLE Nº 3.

RELATIVE EFFECTS OF SEWAGE POLLUTION IN VARIOUS HARBORS.

Harbor	Land Water: Inflow millions of cu. ft. in 12 hours	Total Sewage Inflow millions of cu. ft. in 12 hours	Resulting Land Water Dilution	Sea Water Consumed Available for Dilution millions of cu. ft. in 12 hours	Total Dilution based on Land Water & Sea Water	Dissolved Oxygen % Saturation	Putrescibility of Harbor Water (days)	Wet Sludge Thous. of tons per annum	Wet Sludge tons per mile
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
HAVANA	0.5	0.55	1: 0.9	6.0	1: 11	0.0	1:2200	60	14.0
NEW YORK-1907	1180.0	128.80	1: 9	2210.0	1: 26			10872	8.8
BALTIMORE	2.8	1.75	1: 1.6	43.4	1: 26	23.4	1: 830	304	6.0
NEW YORK-1910	1180.0	55.4	1: 21	2210.0	1: 61	67.0	1: 72.0	8430	3.4
WASHINGTON	500.0	4.5	1: 111	0.0	1: 111	82.0		402	1.3
TAMPA	41.2	0.16	1: 258	11.7	1: 330	66.5		19	0.5
BOSTON	46.6	13.6	1: 3.4	12800.0	1: 930			1630	0.2
SAVANNAH	793.0	0.85	1: 1124	0.0	1: 1124	86.0	1: 13	69	0.1
JACKSONVILLE	556.0	0.31	1: 1790	282.0	1: 2700	88.4		49	0.1
CHARLESTON	103.0	0.18	1: 572	531.6	1: 3620	90.0		20	0.1

30 The method of estimating the quantity of water available for dilution used by Mr. H. de B. Parsons, is as follows. See his "Brief Report on the Tidal Actions in the Harbor of New York."

"The quantity of 'new' sea water entering Upper Bay is:

		In million cubic feet per tidal cycle.
At the Narrows—	Average for year	2,210
	Least amount—(February)	670
	Least amount—(Summer—August)	1,520

"These figures were determined,

1st. From observation of the total tidal flow through the Narrows at ebb tide.

2nd. From daily observation by the salinometer, the records covering a period of over one year as made by the Metropolitan Sewerage Commission. The average of these observations is appended.

"If no land-water entered the harbor, then the water in the harbor would be as salty as that of the sea. The mean quantity of water flowing on ebb tide was divided into land and sea-water by means of the salinometer percentages. The land-water was then divided into 'land-water which will return' and 'land-water which will not return.' The latter was taken as the run-off of the rivers for 12 lunar hours and the former as the remainder of the total land-water as shown by the salinometer.

"The sea-water, as shown by the salinometer was then divided by making the 'sea-water which will not return' the same proportion of the total sea-water as the 'land-water which will not return' is to the total land-water. This is so because the land and sea-water are mixed, and the amount of 'land-water which will not return' will take with its proportionate amount of sea-water.

"The division of water on flood tide was made by taking the total volume of flow on flood and laying off the amounts of land and sea water which will return as shown on ebb. The remainder is the 'new' sea water, or the water which was not in the harbor on the preceding tide. It must be equal to the 'sea water which will not return' as given on ebb.

"The land water as shown by the salinometer is always in excess of the runoff. This is so because the flushing action of the harbor is not complete, as at the end of every ebb tide there remains some land water in the harbor. The amount remaining, which is the amount in excess of the run-off, is variable, due to the seasonal variations."

31 To obtain the amounts of sea and land water which return on succeeding tides, and which is, therefore, not available for dilution, but which may be considered as dead water, swinging back and forth, and which is ultimately displaced by the sewage requires float or current meter measurements to determine the average velocity of the tidal movement in each tidal cycle, the observations being made at some point of known cross section. Such

measurements were obviously impossible in the time available for the work of this Committee, and, therefore, the sea water available for dilution, to be added to the computed land water available for dilution, has been determined by taking the tidal prisms in the assumed tidal areas, affected in each harbor, as shown on the maps of Harbors, Pages 1 to 25.

At Washington and Savanah, the chlorine content in the harbor water was so low as to indicate that the total available dilution was due entirely to the fresh water flow.

At Baltimore, the change in the amount of chlorine in the upper end of the North West Harbor and in the Patapsco River, outside of this harbor, was so slight as to indicate that the fresh water flow was but a very small per cent of the total water available for dilution. Sufficient data were not at hand, however, to determine precisely the relative average salinity of the water in the upper end of the North West Harbor and in the Patapsco River outside of this Harbor for the purpose of cumputing the exact ratio of fresh water to sea water. Under these circumstances, the volume of the tidal prism comprised within the limits of the North West Harbor was taken as the total available water for dilution. As this harbor is a dead end harbor, the tidal prism probably gives a fair rational basis
32 of estimate, and probably a greater dilution than actually
occurs. The resulting dilution of 1 to 26 falls where it should, when the conditions obtaining in Baltimore are compared with those of Havana on the one hand, and those of New York on the other. Moreover, Baltimore Harbor is so putrid that it has evidently passed considerably beyond the critical point, and even should the estimated dilution be somewhat high, there would be a big margin between the true dilution at which general nuisance will occur and the dilution as estimated for Baltimore.

Comparisons made in Jacksonville, between an estimate of the total available dilution based on the assumed tidal prism and one based on salinometer percentages, were found to accord closely.

At Havana, the same method was used as at Baltimore, with comparable results. At the other places, the dilutions were so great that a slight error in stating the total sea water available for dilution would not materially affect the results.

The results given, therefore, should give a fair expression of the actual conditions as to total dilution, and as the range of difference in the resulting dilution in the various harbors is so great, no serious inaccuracy in making general comparisons is introduced.

Some criticism may be made assuming the tidal area of New York as that of Upper New York Bay. This will make no practical difference in the final results. So long as the assumption of the amounts of new land and sea water available for dilution are even approximately accurate, the only effect of extending the tidal area considered so as to include the Hudson and East Rivers, Kill von Kull
33 and Newark Bay, will be to increase the stored water volume
available for dilution. Below mean low water there is a fixed amount of water requisite to fill the depressions constituting, when filled with water, the various bays and rivers. This dead

water, or stored water, is continually replaced, or nenewed, by tidal and land water flow. If, then, the tidal and land water flow were excluded and sewage in amount of that now emptying into the various tributaries to Upper New York Bay were allowed to enter into these basins, it would gradually replace all of the stored or dead water in those basins. If, then, the tidal and land flow were allowed to enter again, the dilution would result only from such flow. The only effect, therefore, of extending the tidal area is to increase the amount of stored water and to somewhat delay the date at which net dilution will obtain. As the process of emptying sewage into streams, rivers and bays tributary to Upper New York Bay is a continuous one, and has continued for many years past, it is safe to assume that the net dilution now effected is the ratio of the new sea and land water passing through the Bay to the sewage passing therethrough. The detailed explanation of the manner of determining these factors for New York is found on Page 30 of this report.

Standards of Purity.

In an attempt to establish some simple standard, limiting the amount of sewage which may be safely discharged into a stream, or tidal estuary, without producing putrefactive nuisance, an effort has been made to fix upon the minimum allowable dilution of the sewage which will result from discharging it into a body of water.

From observations made by Stearns, Hering and Goodnough,
34 the proportion of sewage which can be safely discharged into a stream may be expressed as follows:

Nuisance Probable	1 in 16 to 1 in 23
Nuisance Improbable	1 " 36 " 1 " 45

Roughly speaking, then, a stream may be able to purify one-fiftieth of its volume of sewage, but not one-twentieth. These conclusions were drawn with relation to fresh water streams. Whether or not sea water will absorb more sewage than land water, without producing nuisance, has never been practically determined, but it is worthy of remembrance that sea water, when saturated with oxygen, contains about 20 per cent less oxygen than land water at like temperatures. From this fact alone it seems probable that, for like quantities, land water will dispose of more sewage than sea water.

However this may be, the data presented in Col. 6, Table 3, show clearly that with a dilution of 1 in 26, as in Baltimore, general nuisance will result. The "basin" at the upper end of the North West Harbor in Baltimore is little better than an open cess pool in which septic action is active and from which foul odors emanate. It is no exaggeration to say that the whole North West Harbor is in a state which makes it an injurious nuisance.

Havana furnishes another example of a like nature where the dilution is placed at 1 in 11.

Everyone is more or less familiar with the present conditions in New York Harbor, which are described in detail in several volum-

inous reports. It is sufficient to say that conditions here have not yet reached the acute stage. The results of our observations, therefore, indicate that with an available dilution of one in sixty,
35 a harbor will reasonably, though not perfectly, digest the
sewage emptying into it, but will not do so with a dilution of one in twenty-six. This estimate accords reasonably well with Stearns, Hering and Goodnough, especially so, if the difference in the oxygen content of land and sea water is considered.

Estimates of the sewage tributary to Upper New York Bay in 1940 indicate that the dilution will be reduced at that time to 1 in 26 (Col. 6, Table No. 3) or the same as at present in Baltimore.

The general conclusion to be drawn from this statement is that the New York Harbor is fast approaching the limit of its capacity to digest sewage without resulting general nuisance.

Of course, it must be remembered that the use of dilution ratios as a means of fixing a standard for harbor pollution is, at best, misleading, insofar as it does not express in any way local nuisances which may result to the detriment, not only of property, but of health in the vicinity of sewer outlets. Dispersion and diffusion are so intimately associated with the results to be obtained from dilution that no specific statement of the effect of dilution can be made without knowledge of local conditions.

On the other hand, the amount of dilution does furnish an extended view of general conditions and is of assistance in pointing to general conclusions. It is useful so far, and no farther.

Dissolved Oxygen.

The percentage of saturation of dissolved oxygen in the water of various harbors, as shown in Column 7 of Table No. 3, in-
36 dicates that it follows, in a general way, inversely as the
degree of pollution. In other words, the greater the pollution, the smaller the amount of dissolved oxygen. The figures given are interesting in fixing the probable limits to the amount of dissolved oxygen requisite in harbor waters.

Theoretically, while any dissolved oxygen remains in a water, there should be no putrefaction. As a matter of fact, it has been recognized by authorities at home and abroad that malodorous conditions due to putrefactive action may take place long before the oxygen content of a water has been completely exhausted. The degree of oxygen saturation requisite to prevent malodorous conditions varies with many factors, and opinions on the subject differ widely. At best, this method of gauging permissable pollution, when considered alone, is unsatisfactory, but it may be useful in conjunction with other standards in establishing broad lines of differentiation.

In Baltimore Harbor, with an average dissolved oxygen content of practically 23, marked evidences of putrefactive action were apparent all over the harbor, notwithstanding that the temperature of the water at the time of examination was about 46° F.

In Upper New York Bay, the percentage of saturation of dissolved oxygen is 67, and there are no general evidences of septic action,

such as exist in the North West Harbor at Baltimore. The results of these observations indicate that if the average percentage of saturation of dissolved oxygen in a harbor water falls somewhere between these limits, the nuisances resulting from putrefactive action will follow.

37 Local nuisances near the sewer outfalls may exist, however, in harbors where the average dissolved oxygen content is much higher than the figures just mentioned. At Jacksonville, where the lowest percentage of dissolved oxygen recorded was about 64 per cent, there was evidence of local putrefactive action in the vicinity of several of the sewer outfalls. The same conditions were noted at many other places.

Putrescibility of Harbor Mud.

Unfortunately, as shown in Column No. 8, Table No. 3, your Committee was able to obtain samples of the bottom mud from the harbors of but few of the cities visited. A comparison of the analyses of those samples collected, however, as well as of analyses of bottom mud from lakes and ponds of known purity, as shown in the Table giving the results of "Quantitive Putrescibility Tests on Mud", (Appendix No. 1, Page 69) shows that the degree of putrescibility of harbor muds corresponds generally with the degree of pollution. In Atares Bay, Havana Harbor, where the dilution was least and the dissolved oxygen was exhausted, the mud was putrescible when diluted in twenty-two hundred times its volume of distilled water, in Baltimore Harbor in eight hundred and thirty times its volume of distilled water, while the Massapequa Pond mud was only putrescible when diluted one to seven.

It is to be regretted that quantitive putrescibility tests on the mud of New York Harbor were not carried on by the Metropolitan Sewerage Commission, as such tests may serve as an additional index in fixing upon the permissable limits of the pollution of harbors. They are especially interesting in relation to the development of local nuisances. Every additional slant on this important question is useful, for, with the many varying factors and
38 changing conditions in every harbor, detailed data accumulate rapidly, and one's sense of perception is clouded in a mass of figures and correct conclusions are obscured unless simple tests and simple lines of study are adhered to. It is only upon broad general conclusions that the safe permissable degree of pollution of any harbor can be settled. The problem does not lend itself to refined scientific diagnosis. Broad comparisons along different lines are essential to a conclusion, and quantitive putrescibility tests on mud give a simple additional line of evidence.

Tons of Wet Sludge per Million Cubic Feet of Water Available for Dilution.

Column No. 10 of Table No. 3 gives the tons of wet sludge which will be produced by the estimated amount of sewage (Column No. 3) which will enter into the various harbors listed.

It is seen that the quantity of wet sludge varies in general inversely as the estimated total dilution (Column No. 6).

The amount of wet sludge produced, thus expressed, gives another simple way of gauging the permissable density of pollution, and entirely removes the factor of sewage strength, as the estimates of the quantity of wet sludge have all been reduced to a population basis. (See Appendix No. 3).

It is seen that 14-6/10 tons of wet sludge per million cubic feet of total water available for dilution are delivered into Atares Bay at Havana; 6 tons into the North West Harbor at Baltimore, and 3-4/10 tons into New York tidal waters, at the present time. Assuming that the population of the Metropolitan District of
39 New York will be 12,000,000 in 1940 (Table No. 2, Page 28), and estimating upon the same per capita contribution of wet sludge as produced in 1910, we find that there will be delivered into New York Harbor in 1940, 6-8/10 tons of wet sludge per million cubic feet of new water available for dilution. It is interesting to note that in 1940, the total dilution and tons of wet sludge per million cubic feet of water available for dilution in New York Harbor, will be approximately equal to the figures for the North West Harbor in Baltimore at the present date, where conditions, as has been previously stated, are obnoxious.

Value of Standards.

The difficulty of finding a simple rule, or fixed standard of purity, for use as a medium for the practical expression of the safe limit of pollution, without danger of passing the critical point, at which a harbor or tidal estuary, as a whole, will assume generally unsatisfactory condition, has been referred to in several paragraphs of this report.

Of the standards suggested in this report, the amount of dilution and the oxygen content of the water have been most generally used. A certain amount of dissolved oxygen is required to convert the organic matter in sewage into gases and mineral salts. This leaves the water for the time, deficient in the quantity of dissolved oxygen present. The amount of this deficiency is a measure of the activity of the processes of decomposition and of the capacity of the water to decompose additional organic matter. In the absence of dissolved oxygen, putrefaction takes place, accompanied by foul odors.
40 As has been stated, putrefaction should not occur, theoretically, as long as any dissolved oxygen remains, but, practically, it has been found that it does occur when an appreciable amount of oxygen is present in the water. Opinions differ widely as to the point below which the dissolved oxygen may be safely reduced. Some claim 70 per cent of saturation is necessary to prevent malodorous conditions, others 50 per cent, and some foreign authorities place the limit even lower.

Standards based on the permissable minimum dilution are necessarily founded upon numerous observations of the chemical con-

stituents found in waters, corresponding to such dilutions, on the assumption of a fair normal composition for water and sewage.

Standards of the permissable minimum dilution, as applied to the general conditions in a harbor, must be based on the assumption that sewage is emptied into a body of water of unvarying volume, flowing with sufficient rapidity to prevent deposits. If instead, the sewage is turned into a body of water where the currents are sluggish, the solid particles of the sewage may accumulate and decompose, giving off offensive gases. Fluctuations in tide, where they cause large areas to be alternately covered with water and left bare, as at Lynn, Mass., and large areas of shallow water are unfavorable for the proper disposal of sewage. Marshes are similarly unfit.

The extent of diffusion and dispersion of sewage must be considered in connection with a standard for the minimum permissable dilution, as the total dilution based upon the total flow in a harbor is never safe, for the reason that sewage emptying into a
41 harbor is never so diffused and dispersed as to include the
total flow available for dilution, and then there is the deposition of solid matter at slack tide, causing the accumulation of mud on the harbor bottom and the inability of this mud, as the layers become thicker, to extract oxygen from the water at a sufficient rate to prevent putrefactive action. The form and depth of the sewer outlet, its location, the density of harbor water, as well as its temperature, to some extent its turbidity, and the tidal movement at the outlet must all be considered. Density, dispersion, diffusion, dilution and depth are each important modifying elements.

In short, there are many things which require careful consideration in each case, and many factors which cause a considerable variation from any general rule which may be laid down. The factors affecting standards based on the minimum permissable dilution affect equally as well as standards based on the dissolved oxygen content of harbor waters, or the other standards which have been proposed from time to time, such as the determination of free and albuminoid ammonia, of nitrates, putrescibility tests, and a combination of the tests for nitrates, or the ammonias, and dissolved oxygen.

Many authorities in England claim that no test or standard of any value has as yet been determined, and this view cannot be criticised insofar as there is certainly no general standard which suggests the local and specific nuisance which may occur as a result of emptying sewage into adjacent tidal waters, even though the general conditions are such as not to affect the human senses appreciably.

42 Your Committee have added the "Quantitive Putrescibility Tests on Harbor Muds," as they express more particularly the condition of the deposed suspended organic matter carried by the sewage and which usually cause the putrefactive odors.

It is not impossible to have a large theoretical dilution and a reasonably high oxygen content and yet encounter the putrefactive action of mud on a harbor bottom. When this action occurs, odors and consequent nuisance will be produced in greater or less amounts

depending upon local conditions, and it seems, therefore, that an important factor in the determination of the safe general limits of pollution in a harbor should take into consideration some standard relating to the permissable putrescibility of harbor mud.

It may be said, indeed, in nearly all cases, that at the outlets of outfall sewers, where the deposition of suspended matter is greatest, the olfactory nuisance frequently occasioned, arises more from the putrefaction of the mud than from the presence of sewage in the vicinity.

The last standard suggested in this report of the allowable tons of wet sludge, per million cubic feet of available water for dilution, is more definite than the simple method of expressing dilution as a ratio between the volume of sewage and the volume of water into which it discharges, for the reason that sewage strength varies with its per capita volume and the total amount of organic matter to be digested is really a function of the population served rather than of sewage volume.

Your Committee does not feel that the standards presented
43 are necessarily interpretable within close limits, but that, when considered together, they harmonize sufficiently to convey in a clear general way the critical point at which the general condition of a harbor will become offensive.

Form of Nuisance.

Various terms have been used to express an undesirable condition in a harbor or stream resulting from sewage pollution. It is customary to sum up the whole condition resulting from sewage pollution under the generic term of "Nuisance," and attempts have frequently been made to classify the different kinds of nuisances resulting from the presence of sewage in harbors.

The first classification which naturally suggests itself is that of general and local, the general nuisance relating more specifically to those conditions which prevail in harbors which have been grossly polluted, and where the area affected by nuisance is co-extensive, or nearly so, with the harbor area, or at least with the area of a large section of the harbor.

Local nuisances refer more particularly to those, resulting in the vicinity of sewer outfalls, or those found in restricted or confined areas.

Nuisances also may be classified as "sensible," of which class there are two sub-divisions, namely, "visual" and "olfactory."

Another form of nuisance may be "injurious," and in this class may be included "infective" nuisances, or nuisances which produce sickness through infection resulting therefrom. Sensible nuisances, while not necessarily infectious, may produce injury to property, as, for instance, through the soiling of beaches, through the
44 injury to paint by the evolution of hydrogen sulphide, through the depreciation of property by the stench developed or by visual filth.

Definition of Nuisance.

It is no less difficult to phrase a definition expressing the condition which constitutes a nuisance than it has been shown to be to establish a simple rule or standard for determining the critical point at which a general nuisance will result.

The following definition, however, is offered as a reasonable one: A state, condition or thing which produces involuntary repugnance through the senses of a normal man, or which causes injury to the property or health of man.

It is not necessary for a nuisance to become general in order for it to conform to this definition, and yet it must be admitted that the definition is a reasonable one, as it applies more specifically to man's comfort than to his esthetic sense. It is uncomfortable for the normal man to live or work in a stench, or to be surrounded by visual filth. It is uncomfortable to be damaged in person or property. The use of a harbor in such a way as to transgress the just restrictions upon such use, which the proximity of other persons or property, in a civilized community, imposes upon what would otherwise be rightful freedom, is a nuisance. It is not necessary for the entire community to suffer discomfort; if only a fractional part does so, then just restrictions are transgressed. The number of people
45 affected has only to do with the extent of the nuisance, its quantitive and not its qualitive aspect.

Local Nuisance.

Long before a harbor has become a general nuisance, as in the case of the North West Harbor at Baltimore, local nuisance occurs as a result of sewage pollution.

An estimate of the extent and degree of the local nuisance resulting from sewage is dependent upon many factors, and it is necessary to deal with conditions as they have been observed to exist in order that such an estimate may be accurate.

Appearance of Sewage.

When an average sample of unscreened or unsettled sewage is placed in a bottle, the sewage has a dirty, gray color; if fresh, a musty and rather unpleasant odor, and if stale, a decidedly disagreeable odor, not unlike that of hydrogen sulphide. It contains the usual sewage filth, toilet paper, broken down feces, grease balls, trash, match sticks, etc. The particles of suspended matter vary materially in size. The small solid particles are usually composed of fecal matter, disintegrated paper, fiber and cloth, and ordinary detritus. When allowed to stand, much of the suspended matter settles down, causing a dirty, gray slimy sludge to accumulate at the bottom. If allowed to stand at summer temperature, the sewage becomes putrid. If greatly diluted, the sewage does not putrify, nor give off offensive odors, the decomposable organic substances being gradually
46 oxidized and converted into harmless and inoffensive compounds. The offensive odors of putrefaction are produced when the natural purifying agencies are overtaxed.

When crude sewage is emptied into a harbor it carries with it all of the suspended matter which is inherent in it, and the suspended matter and detritus in the sewage creates the visual nuisance.

When a sewage is discharged into a harbor where the turbidity is low, a marked discoloration of the water usually occurs and the water contains a large mass of visible particles of the paper, feces, and other solid matter, and the water of the harbor becomes decidedly turbid. The surface which is discolored is frequently sharply separated from the surrounding water, and as the current or tide carries the sewage away from the outfall, this discoloration expands.

As a rule, the sewage keeps its integrity well, but it eventually loses its turbidity by intermixture with the waters into which it is discharged.

The surface of this discolored area is usually covered with a film of grease. This greasy film is persistent and usually lasts longer than the discolored area with which it is first associated. Long after the turbidity has disappeared from the surface, particles of paper and suspended matter, and minute white flakes in large numbers may be observed. The white flakes consist largely of insoluble soap which have been produced by chemical combination between soluble soap and the calcium and magnesium salts, which are present in both salt and fresh water.

47

Density.

Sewage when discharged into sea water will rise to the surface, and this rise is due chiefly to the difference in specific gravity between the two liquids.

Turbidity.

Turbid waters act as a mask to shield visual effects. In Washington and Savannah, this was marked and no doubt the visual nuisance in waters with a turbidity of above fifty parts per million will be confined within very restricted limits.

Visual Sewage Field.

When sewage is emptied into a harbor at the surface, it spreads out over the surface water in the vicinity of the outlet, carrying with it the filth, the specific gravity of which is insufficient to cause immediate settlement.

If sewage is discharged horizontally below the surface of a harbor, the inflowing sewage preserves its integrity for a considerable distance, depending upon its initial velocity at the outlet, and rising upwards, spreads out in a layer upon the surface, and carrying with it, as before, the suspended filth which does not readily settle.

If directed upward vertically, the discharged sewage immediately rises to the top in a gradually enlarging column, forming a mushroom shaped cone at the surface, and spreading out thinly at the top upon the water surface.

If deflected downward at the outlet, the sewage spreads to some ex-

tent at the sewer opening, and, reversing its direction of flow,
48 rises upwards about the opening of the sewer and spreads out
on the surface.

The rate at which the sewage will rise is a function of the relative density, or salinity, of the harbor water and of the sewage discharged. The greater the salinity of the water, the more rapid the rise. Temperature, also, plays some part in this phenomenon, and the greater the difference in temperature between the sewage and the water, the greater the rate at which the sewage rises to the top. The observations of your Committee, however, lead them to believe that the temperature effects are considerably less by comparison than those caused by differences in salinity.

The tides, or currents, in a harbor, passing the sewer outlet distort to a greater or lesser extent, depending upon the velocity of those tides or currents, the normal curves, or lines, which the rising sewage would follow in still water, and thus change in some small degree the location of the point at which the rising sewage stream intersects the surface of the harbor water. At ordinary depths, however, the deflection of the sewage as a result of tidal, or current velocities, is not sufficient to remove the visual effects produced on the water surface.

Observations of the sewer outfalls at Havana, Tampa, Jacksonville, Savannah, Charleston and Washington prove that the general statements, above made, with relation to the action of sewage thus discharged, are not affected materially by tides or currents. These
outfalls included those discharging horizontally at the harbor
49 surface, horizontally below the surface, vertically below the
surface, and downward below the surface, those placed below
the surface varying in depth from nine to thirty feet below mean tide.

When the sewage reaches the surface it gradually spreads, actuated by the influence of surface currents, winds and tidal phenomena. The shape and form of the visual sewage field is materially affected by local conditions with respect to these elements, and no broad statement can be made. The location of the sewer outlet has a marked effect upon the form of the sewage field. For instance, if the outlet is adjacent to the shore, where the velocity of the current is retarded, the sewage field hugs closely to the shore and parallel to it, following the general direction of the current in mid stream, and forming a long, narrow parallelogram. If the outfall is carried nearer mid stream, the sewage field follows the direction of the current taking the form of a distorted trapezoid or trapezium, with its longest axis parallel to the direction of tidal or current flow, its form depending to a great extent upon the direction and velocity of the wind.

The sewage field is movable with the tides, currents and winds, swings up or down stream as the tide reverses, and spreads out or contracts under the influence of the wind.

As the sewage field spreads, diffusion takes place gradually, until, at some observable limit, varying in distance on divergent radii, from the outlet as a center, the visual field disappears. At this point

the visual nuisance ceases, but deposition of the suspended
50 matter may continue for great distances and under proper conditions this deposition may produce olfactory nuisance. Infective nuisance may continue beyond the limits of the olfactory nuisance produced by the putrefactive action of the bottom mud formed by the deposition of solids.

Diffusion and Dispersion.

The suspended matter contained in the sewage is carried from point to point by the tidal currents and by the action of the wind. Some of the solids may be carried several miles without losing their characteristics. The mixture, however, between sewage and harbor water goes on progressively, taking place from the outside edge of the discolored area. The greatest diffusion proceeds apparently from the bottom of the sewage mass.

The transporting power of water for suspended sewage solids varies as the square of the velocity of the moving current. Therefore, if the velocity is reduced by one-half, the capacity of the water to carry solid particles in suspension will be reduced to one-quarter. The effect of the velocity of current on transporting power is a very important element in the dispersion of sewage matter, for when harbor water becomes slack by reason of the change of tide, deposition goes on rapidly beneath the sewage field, piling up the sewage sludge on the bottom, there to lie and putrefy, and as the odors caused by the putrefaction of deposits upon the bottom are the most intense and offensive of any odors produced by the discharge of sewage into a harbor, the manner of dispersion and diffusion of the sewage plays an important part in the local nuisances produced.

51 Another factor in the dispersion of sewage, and one which should not be overlooked, is that the relative rate of deposition of solid matter in sea water is much greater than in fresh water. Water which is strongly saline will not transport as much solid matter in suspension as will water without salt. The capacity of a harbor, therefore, for carrying sewage matter to sea cannot be safely estimated from the information obtained merely from a study of inland rivers.

It may be said, in general, that deposits of sewage sludge exist not only in the immediate neighborhood of sewage outfalls, but to a degree, for considerable distances from these outfalls.

Local sewage discharge, therefore, may cause grave sensible nuisance, extending over large areas and in considering the problem of harbor pollution these local nuisances must be of prime consideration, even though a larger area of harbor may be unaffected by them. Standards for dilution, for the permissible per cent of oxygen saturation, or other standards, based on general averages, are no guide to the local nuisance which may result. A study of local physical conditions at sewage outfalls, as they exist, is essential to a conclusion.

51a Chemical Studies.

In addition to the field determinations of dissolved oxygen, salinity, turbidity and the putrescibility of muds, special experiments were conducted by Mr. Leon R. Whitcomb, chemist in the laboratory of one of your Committee, Mr. Nicholas S. Hill, Jr., with relation to the comparative results obtained by the Winkler and Levy methods for the determination of dissolved oxygen, and also for the purpose of determining the effect of nitrites in the accuracy of the Winkler method.

The laboratory methods and apparatus used, together with detailed description of the work outlined above, is given in Appendix IV.

The results which are shown in the Tables Appendix IV have been corroborated by independent investigations conducted by Dr. Jackson at the Mount Prospect Laboratory.

51b Summary and Conclusions.

1. A general nuisance will, under ordinary conditions, result in a harbor into which sewage is emptied:

a. When the dilution approaches 1-26.

b. When the per cent of saturation with dissolved oxygen falls to 23.5.

c. When the number of tons of wet sludge per million cubic feet of total new water, available for dilution, amounts to 6.

2. A general nuisance may occur in a harbor into which sewage is emptied:

a. When the ratio of dilution falls at some point between 1-60 and 1-30.

b. When the per cent of saturation with dissolved oxygen falls at some point between 65 and 23.5.

c. When the number of tons of wet sludge per million cubic feet of total new water, available for dilution, amounts to between 3.5 and 6.

3. A general nuisance will not occur in a harbor into which sewage is emptied under ordinary conditions:

a. When the ratio of dilution exceeds 1-60.

b. When the per cent of saturation with dissolved oxygen exceeds 65.

c. When the number of tons of wet sludge per million cubic feet of total new water, available for dilution, is less than 3.5.

4. No standards or rules relating to general conditions give a basis upon which an estimate can be made of the extent to which local nuisances may occur.

5. Serious local nuisances, sensible, injurious and infectious, frequently occur where there is no general nuisance.

51c 6. The present pollution of New York Harbor is approaching the critical point at which a general nuisance may occur.

7. If the crude sewage from the Metropolitan Sewerage District, or a large part of it, continues to be discharged into the tidal waters

in the vicinity of New York, up to 1940, serious general nuisance will probably result at, or before, that time.

8. Serious local nuisances now exist in New York Harbor.

9. It seems from comparative experiments conducted with the Levy and Winkler methods for the determination of dissolved oxygen, that the true percentage of dissolved oxygen presented in this report, and as stated for New York Harbor by the Metropolitan Sewerage Commission and the Central Committee Experts, is, if anything, rather higher than the true percentages which actually obtain.

10. To discharge crude sewage from the Passaic Valley Sewerage District, in the amounts proposed, and at the point selected at Robbins Reef, would create another local nuisance of wide extent and materially hasten the approach to the critical point at which a general nuisance will exist in Upper New York Bay.

Respectfully submitted,

DANIEL D. JACKSON.
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March 15, 1912.

52 APPENDIX I.

Giving Basic Data and Explanation of the Method of Obtaining Land-water Drainage Areas Tributary to the Harbors Considered, the Annual Rainfall in These Drainage Areas, the Volume of Land Water Flow, the Tidal Ranges and Tidal Areas of the Harbors Considered, and the Normal Characteristics of the Harbor Waters (Table No. 1, Page 28).

A. The Tributary Land Water Drainage Area, Col. 2, in the case of each harbor, has been carefully computed from the best obtainable maps.

For Havana, no reliable map was obtainable, and the statement of Mr. H. E. Hyde of the Obras Publicas, Havana, has been accepted.

For New York, the area is given as stated on Page 14 of the Central Committee's "Basic Physical Data Relating to the Metropolitan and Passaic Valley Sewerage Districts.

For Baltimore and Boston, it was computed from the topographical maps of the United States Geological Survey.

For Washington, the drainage area of the Potomac River is taken as stated in a paper on "Hydrography of the Potomac Basin," Trans. Am. Soc. C. E., Vol. XXVII, Page 21 et seq.

For Savannah, the drainage area of the Savannah River above Augusta was obtained from Water Supply and Irrigation Paper No. 204. Below Augusta, and above Savannah, it was computed from a State map of Georgia, published by the Georgia State Geo-
53 logical Survey, and the total area thus derived was checked with local estimates.

For Tampa, Jacksonville and Charleston, it has been taken from the United States Post Route maps.

(Table 2— #178)

-RAINFALL AND RUNOFF.-

-VARIOUS STREAMS ALONG SOUTH ATLANTIC COAST.-

	Month	-Maximum Year.-1901.- Rainfall. Inches in Depth	Runoff Inches in Depth	% of Runoff to Rainfall	Average Year.-1898-1908 Rainfall Inches in Depth	Runoff Inches in Depth	% of Runoff to Rainfall	Minimum Year.-1904. Rainfall. Inches in Depth	Runoff. Inches in Depth	% of Runoff to Rainfall
Broad River, Ga., near Carlton, Ga. Drainage Area = 762 Sq. Mi.	Jan.	5.40	3.17	58.7	4.14	2.30	55.6	3.10	1.12	36.2
	Feb.	3.47	2.32	67.0	6.02	3.32	55.1	4.25	1.58	37.2
	Mar.	6.21	3.42	55.1	5.72	3.47	60.6	4.04	1.89	46.8
	Apr.	6.84	3.55	51.9	4.24	2.27	53.6	2.09	1.05	50.3
	May	5.97	2.54	42.6	3.27	1.62	49.5	2.58	0.95	36.8
	June	6.04	3.44	57.0	4.74	1.83	38.6	3.40	0.70	20.6
	July	4.25	1.93	45.4	5.26	1.79	34.0	3.29	0.79	24.0
	Aug.	13.64	4.83	30.9	6.71	2.44	36.3	7.06	2.13	30.2
	Sept.	5.55	3.14	56.6	4.21	1.71	40.6	0.94	0.69	73.4
	Oct.	1.12	1.64	146.4	3.05	1.33	43.6	0.24	0.47	195.8
	Nov.	0.62	1.32	212.9	2.96	1.21	40.9	2.81	0.64	22.8
	Dec.	6.83	4.18	61.2	5.18	2.18	42.1	4.08	1.04	25.5
	TOTALS	67.94	35.48	52.2	55.50	25.47	45.9	37.88	13.05	34.5

	Month	Maximum Year.-1908.- Rainfall. Inches in Depth	Runoff Inches in Depth	% of Runoff to Rainfall	Average Year.-1899-1908. Rainfall. Inches in Depth	Runoff. Inches in Depth	% of Runoff to Rainfall	Minimum Year.-1904.- Rainfall. Inches in Depth	Runoff. Inches in Depth	% of Runoff to Rainfall
Savannah River, at Augusta, Ga., Drainage Area 7294 Sq. Mi. [1899-1906] at Woodlawn, S.C., Drainage Area 6600 Sq. Mi.- [1907 & 1908]	Jan.	5.42	3.44	63.4	4.08	2.16	52.9	2.96	0.88	29.7
	Feb.	6.22	4.20	67.6	6.17	3.24	52.5	4.34	1.36	31.4
	Mar.	4.78	3.02	63.2	5.24	3.10	59.3	3.84	1.36	35.4
	Apr.	6.57	3.22	49.1	3.97	2.08	52.4	1.94	0.84	43.3
	May	2.15	1.72	80.0	3.34	1.45	43.4	2.68	0.68	25.4
	June	4.80	2.16	45.0	5.20	1.86	35.8	3.47	0.62	17.9
	July	5.49	1.80	32.8	4.83	1.45	30.0	3.81	0.60	15.8
	Aug.	11.83	4.59	38.8	6.60	1.94	29.4	7.82	1.86	23.8
	Sept.	2.29	1.76	76.9	3.86	1.39	36.0	1.07	0.58	54.1
	Oct.	4.76	1.56	32.8	2.65	1.12	42.3	0.27	0.33	122.2
	Nov.	1.80	1.67	92.8	2.61	1.04	39.9	2.71	0.46	17.0
	Dec.	4.53	2.48	54.8	5.30	1.94	36.6	4.04	0.75	18.6
	TOTALS.	60.64	31.62	52.2	53.85	22.77	42.2	38.95	10.33	26.5

(Table B - #178)

-RAINFALL AND RUNOFF.-

-VARIOUS STREAMS ALONG SOUTH ATLANTIC COAST.-

	Month.	Maximum Year.-1900.-			Average Year.-1893-1908.			Minimum Year.-1904.		
		Rainfall Inches in Depth	Runoff Inches in Depth	% of Runoff to Rainfall.	Rainfall. Inches in Depth	Runoff. Inches in Depth	% of Runoff to Rainfall.	Rainfall. Inches in Depth	Runoff Inches in Depth	% of Runoff to Rainfall.
Ocmulgee River at Macon, Ga.	Jan.	2.09	0.73	34.9	3.76	1.46	38.8	3.12	0.98	31.4
	Feb.	9.23	416	45.1	5.40	2.48	45.9	3.83	1.40	36.6
	Mar.	4.16	2.21	53.1	4.75	2.56	53.9	2.22	1.05	47.5
	Apr.	5.82	3.22	55.3	3.91	1.84	47.1	1.60	0.71	44.4
	May	2.45	1.36	56.6	2.94	0.98	33.3	2.20	0.53	24.1
Drainage Area = 2425 Sq. Mi.	June	7.83	3.78	48.3	3.68	1.18	32.1	2.24	0.47	21.0
	July	4.03	1.72	42.7	4.73	1.18	25.0	3.37	0.37	11.0
	Aug.	4.29	0.95	22.1	5.24	1.25	23.8	8.03	1.41	17.6
	Sept.	2.98	1.18	39.6	2.82	0.97	34.4	0.58	0.31	53.5
	Oct.	1.99	0.89	44.7	2.62	0.86	32.8	0.29	0.14	48.2
	Nov.	3.95	1.06	26.8	2.66	0.79	29.7	2.98	0.28	9.4
	Dec.	6.44	1.94	30.2	4.35	1.36	31.2	4.10	0.62	15.1
	TOTALS	55.26	23.20	42.0	46.87	16.91	36.1	34.56	8.26	23.9

	Month.	Maximum Year.-1901.-			Average Year.-1899-1906.			Minimum Year.-1904.-		
		Rainfall. Inches in Depth	Runoff.- Inches in Depth	% of Runoff to Rainfall.	Rainfall. Inches in Depth	Runoff Inches in Depth	% of Runoff to Rainfall.	Rainfall. Inches in Depth	Runoff Inches in Depth	% of Runoff to Rainfall.
	Jan.	3.87	2.60	67.1	3.37	1.82	54.0	2.87	1.07	37.3
Oconee River at Dublin, Ga.	Feb.	4.02	2.32	58.6	6.11	2.74	44.8	4.15	1.70	41.0
	Mar.	5.58	1.79	32.1	5.01	2.68	53.5	2.39	1.30	54.6
	Apr.	3.99	3.28	82.1	2.79	2.03	72.7	1.21	0.74	61.1
	May	4.12	1.18	28.6	3.05	1.03	33.8	2.23	0.52	23.3
	June	6.48	2.15	33.2	4.88	1.28	26.4	2.06	0.39	18.9
Drainage Area = 4182 Sq. Mi.	July	4.37	1.18	27.0	4.52	1.02	22.6	2.44	0.32	13.1
	Aug.	7.57	1.65	21.8	5.16	0.99	19.2	6.67	1.00	15.0
	Sept.	4.73	2.14	45.3	2.75	0.81	29.5	0.95	0.30	31.6
	Oct.	0.90	0.84	93.3	2.55	0.66	25.9	0.52	0.17	32.6
	Nov.	1.07	0.62	58.0	2.29	0.58	25.3	2.95	0.32	10.8
	Dec.	4.73	1.22	25.8	4.58	1.20	26.2	4.06	0.64	15.8
	TOTALS	51.43	20.98	40.8	47.06	16.84	35.8	32.49	8.47	26.1

(Table C #178)

- RAINFALL AND RUNOFF. -

- VARIOUS STREAMS ALONG SOUTH ATLANTIC COAST. -

		Maximum Year. - 1903. -			Average Year. - 1902 - 1907.			Minimum Year. - 1904. -		
	Month.	Rainfall Inches in Depth	Runoff Inches in Depth	% of Runoff to Rainfall.	Rainfall. Inches in Depth	Runoff Inches in Depth	% of Runoff to Rainfall.	Rainfall. Inches in Depth	Runoff Inches in Depth	% of Runoff to Rainfall
Broad River, S. C., near Alston, S. C.	Jan.	3.26	2.47	70.7	2.88	2.31	802	2.92	0.98	33.5
	Feb.	8.04	5.11	63.5	4.79	2.94	61.4	3.66	1.69	46.2
	Mar.	7.06	6.40	907	3.72	3.13	842	2.91	1.78	61.1
	Apr.	3.35	3.77	112.5	2.88	1.85	64.2	1.48	1.08	73.0
Drainage Area = 4,609 Sq. Mi.	May	2.30	1.61	70.0	3.53	1.40	39.6	2.11	0.92	43.6
	June	8.90	5.04	56.6	4.96	2.10	42.3	2.47	0.95	38.4
	July	2.78	1.11	40.0	4.69	1.42	30.3	6.19	1.04	16.8
	Aug.	5.03	1.71	34.0	6.24	2.15	34.4	6.55	3.06	46.7
	Sept.	3.70	1.07	29.0	3.37	1.18	35.0	1.19	0.67	56.3
	Oct.	2.92	0.78	26.7	2.65	0.95	35.8	0.88	0.40	45.4
	Nov.	1.33	0.88	66.1	4.33	1.01	43.3	3.11	0.73	23.4
	Dec.	1.62	0.90	55.5	4.24	2.20	51.9	3.41	1.22	35.8
	TOTALS.	50.29	30.85	61.4	46.28	22.64	49.0	36.88	1455	39.6

		- Maximum Year. - 1889. -			Average Year. - 1889 - 1902. -			Minimum Year. - 1898. -		
	Month	Rainfall. Inches in Depth	Runoff. Inches in Depth	% of Runoff to Rainfall	Rainfall Inches in Depth	Runoff Inches in Depth	% of Runoff to Rainfall	Rainfall. Inches in Depth	Runoff. Inches in Depth	% of Runoff to Rainfall.
Cape Fear River, at Fayetteville, N.C.	Jan.	6.71	4.46	66.2	3.71	1.81	48.8	1.94	0.54	27.8
	Feb.	4.24	4.00	94.5	4.29	2.53	59.0	0.95	0.41	43.2
	Mar.	2.33	1.39	59.5	3.89	2.13	54.7	4.41	0.85	19.3
	Apr.	2.76	1.34	48.6	3.37	1.63	48.4	3.36	1.09	32.5
	May	4.77	0.51	10.7	4.77	1.05	22.0	3.73	0.61	16.4
Drainage Area = 4,493 Sq. Mi.	June	5.03	1.76	34.9	4.19	0.81	19.3	3.12	0.29	9.3
	July	14.04	5.33	37.9	6.11	1.27	20.8	4.72	0.71	15.1
	Aug.	6.96	4.07	58.4	5.69	1.47	25.8	8.05	1.45	18.0
	Sept	3.68	0.85	23.1	3.80	0.79	20.8	3.39	0.91	26.8
	Oct.	3.32	0.86	25.9	3.28	0.73	22.2	3.78	0.45	11.9
	Nov.	3.23	1.94	60.0	2.65	0.65	24.5	3.23	0.73	22.6
	Dec.	0.64	0.63	98.4	2.90	0.89	30.7	2.23	0.86	38.6
	TOTALS	57.71	27.41	42.6	48.65	15.76	32.4	42.91	890	20.7

-RAINFALL AND RUNOFF.-

VARIOUS STREAMS ALONG SOUTH ATLANTIC COAST.-

	Month	Maximum Year.-1901.- Rainfall Inches in Depth	Runoff Inches in Depth	% of Runoff to Rainfall	Average Year.-1897-1904. Rainfall Inches in Depth	Runoff. Inches in Depth	% of Runoff to Rainfall	Minimum Year.-1904. Rainfall. Inches in Depth	Runoff. Inches in Depth	% of Runoff to Rainfall
Roanoke River at Roanoke, Va. Drainage Area = 388 Sq. Mi.	Jan.	2.36	1.49	63.2	2.80	1.51	54.0	2.08	0.45	21.6
	Feb.	0.71	0.66	93.0	3.81	2.54	66.7	1.90	0.64	33.6
	Mar.	3.26	1.58	48.5	4.23	3.01	72.8	2.44	1.18	48.4
	Apr.	6.50	4.90	75.4	2.92	1.98	67.8	2.28	0.58	25.4
	May	7.46	4.36	58.4	3.79	1.72	45.4	3.44	0.87	25.2
	June	7.06	2.54	35.9	5.04	1.17	23.2	8.14	1.19	14.6
	July	5.26	2.55	48.4	4.08	0.86	21.0	5.10	0.78	15.3
	Aug.	10.72	5.72	53.3	3.78	1.35	35.7	3.31	1.35	40.7
	Sept.	3.52	1.30	37.0	3.33	0.73	21.9	1.22	0.38	31.2
	Oct.	0.86	0.79	91.9	2.94	0.91	30.9	0.13	0.27	207.8
	Nov.	1.04	0.53	51.0	2.24	0.72	32.2	1.87	0.32	17.1
	Dec.	7.45	4.23	56.7	3.23	1.40	43.3	3.16	0.35	11.1
	TOTALS.	56.20	30.65	54.5	42.19	17.90	42.4	35.07	8.36	23.8

(Table E - #178)

- RAINFALL AND RUNOFF. -

- VARIOUS STREAMS ALONG NORTH ATLANTIC COAST. -

	Month.	Maximum Year - 1901. -			Average Year - 1868-1908			Minimum Year - 1880. -		
		Rainfall. Inches in Depth	Runoff. Inches in Depth	% of Runoff to Rainfall	Rainfall. Inches in Depth	Run off. Inches in Depth	% of Runoff to Rainfall.	Rainfall. Inches in Depth	Runoff. Inches in Depth	% of Runoff to Rainfall.
Croton River, N.Y.	Jan.	1.63	1.15	70.5	4.10	2.65	64.6	3.43	2.38	69.4
	Feb.	0.84	0.54	64.3	4.05	3.13	77.2	3.40	2.92	85.8
Drainage Area = 338.8 Sq. Mi.	Mar.	7.18	5.10	71.0	4.23	4.24	100.2	3.90	2.74	70.2
	Apr.	8.19	7.63	93.2	3.38	3.25	96.2	3.57	1.99	55.8
	May	7.01	4.29	61.2	3.89	1.98	50.9	1.04	0.88	84.6
	June	1.48	1.72	116.2	3.59	1.18	33.8	1.40	0.35	25.0
Note; Runoff Figures reduced to Zero Evaporation from Reservoir surfaces.	July	8.35	1.46	17.5	4.74	0.71	15.0	5.86	0.29	4.9
	Aug.	9.03	3.74	41.4	4.96	1.06	21.4	4.16	0.17	4.1
	Sept	5.49	2.24	40.8	4.23	1.05	24.8	2.42	0.25	10.3
	Oct.	3.94	2.58	65.5	4.05	1.18	29.1	2.83	0.17	6.0
	Nov.	1.80	1.21	67.2	3.80	1.65	43.4	2.32	0.47	20.6
	Dec.	8.81	4.40	49.9	3.93	2.09	53.2	2.59	0.33	12.7
	TOTALS	63.75	36.06	56.6	48.95	24.17	49.4	36.92	12.94	35.1

	Month.	Maximum Year - 1888. -			Average Year - 1875-1908.			Minimum Year - 1883. -		
		Rainfall. Inches in Depth	Runoff. Inches in Depth	% of Runoff to Rainfall	Rainfall Inches in Depth	Runoff. Inches in Depth	% of Runoff to Rainfall.	Rainfall. Inches in Depth	Run off. Inches in Depth	% of Runoff to Rainfall.
Sudbury River, Mass	Jan.	4.13	1.84	44.3	4.14	2.18	52.7	2.81	0.58	20.6
	Feb.	3.68	3.41	92.6	4.18	3.05	73.0	3.87	1.81	46.8
Drainage Area = 75.2 Sq. Mi.	Mar.	6.02	5.66	94.0	4.50	5.06	112.5	1.78	2.82	158.4
	Apr.	2.43	4.63	190.5	3.50	3.59	102.6	1.84	2.36	128.2
	May	4.82	2.86	59.4	3.42	1.93	56.5	4.19	1.64	39.1
	June	2.54	0.73	28.7	3.11	0.91	29.2	2.40	0.52	21.6
	July	1.41	0.20	14.2	3.66	0.33	9.0	2.68	0.20	7.5
	Aug.	6.22	0.66	10.6	3.91	0.46	11.7	0.73	0.14	19.2
	Sept.	8.59	2.02	23.6	3.51	0.46	13.1	1.52	0.16	10.5
	Oct.	4.99	3.50	70.0	4.07	0.85	20.8	5.60	0.32	5.7
	Nov.	7.22	4.82	66.8	3.84	1.49	38.8	1.81	0.36	19.9
	Dec.	5.40	5.32	98.4	3.84	1.86	48.5	3.55	0.34	9.6
	TOTALS.	57.47	35.65	62.1	45.68	22.17	48.5	32.78	11.25	34.3

B. The Mean Annual Rainfall, Col. 3.

For Havana, was estimated from data relating to the State of Florida, obtained from the United States Weather Bureau.

For Baltimore, the value used is that given by the records of the Baltimore City Water Department.

For Washington, the mean annual rainfall for the Potomac Basin was obtained from the paper on Rainfall and Stream Flow by John C. Hoyt, Trans. Am. Soc. C. E.; Vol. LIX, Page 455.

For Savannah, the figures given in the Table, Page 54, of the rainfall in the Savannah River Basin were used. The rainfall figures used in this table, as well as in the tables for the Ocmulgee, Oconee, Broad, Cape Fear and Roanoke Rivers were obtained from published reports of the United States Weather Bureau and were carefully compiled.

For Tampa, Jacksonville and Charleston, values have been obtained from a careful study of the data on rainfall in the basins of comparable southern rivers shown in the tables, Pages 54 to 57.

For Boston, the figures for the Sudbury River shown in the Table, Page 58, are used, these figures having been carefully compiled from the records of the "Boston Metropolitan Water and Sewerage Board," published in their reports.

(Here follow tables marked A, B, C, D, and E, pages 54, 55, 56, 57 and 58.)

59 C. The Fresh Water Flow, Col. 5, or Total Available Run-off.

At Havana, was estimated from the best data available, and taken at one (1) second foot per square mile.

At Baltimore, in estimating the total run-off available from the basin of Jones Falls, an area sufficient to supply the quantity of water taken from the stream, for water supply purposes, has been deducted from the total area of the basin, and the resulting quantity of run off has been checked against the records of the Baltimore City Water Department of the flow of Jones Falls, from which the City obtains a portion of its water supply.

At Washington, the volume of run off has been computed from the data presented in the paper on "Hydrology of the Potomac Basin, Trans. Am. Soc. C. E. Vol. XXVII, Page 21 et seq., and checked against gaugings of the Potomac River reported by the Superintendent of Sewers, Washington, D. C., in his report for the year 1910.

At Tampa, Charleston and Jacksonville, the run-off has been estimated by assuming 40 per cent of the rainfall as available run-off, 40 per cent being estimated from a careful study of the comparable southern rivers, data for which *is* shown in the tables, Pages 54-57.

At Savannah, the runoff was computed from the data shown in the Table, Page 54, which has been carefully compiled from gaugings of the Savannah River reported in the publications of the United States Geological Survey.

60 At Boston, the run-off was computed from data for the Sudbury River shown in the table, Page 58, which has been carefully compiled from the published records of gaugings made by the Boston Metropolitan Water and Sewerage Board.

D. The Tidal Range, Col. 6.

In Upper New York Bay was obtained from the "Report of the New York Metropolitan Sewerage Commission, 1910," Page 156.

For Boston, from the statement of the Boston Metropolitan Water and Sewerage Board.

For Charleston, from the office of the Charleston City Engineer, and

For the other harbors from local sources, and checked against the tidal range given on the United States Coast and Geodetic Survey Charts of the harbors in question.

E. The Tidal Area Considered, Col. 7.

For New York is the area of Upper New York Bay as stated on Page 156 of the "Report of the Metropolitan Sewerage Commission of New York, 1910."

For Boston, the tidal area is used as stated on Page 147 of Appendix XIX of the "Report on Sewage Disposal of Paterson, N. J." by Allen Hazen.

For the other harbors the tidal area has been computed from the harbor charts of the United States Coast and Geodetic Survey.

F. The Physical and Chemical Characteristics of the Harbor Waters, Cols. 8, 9, 10 and 11, have been taken from the Tables Pages

([illegible])

EXAMINATION OF HAVANA HARBOR WATER

NO.	TIME	TEMP	TURB.	CHLORINE	DIS. OXYGEN		REMARKS
					Pts per M	% Sat.	
1	9/12 1911 11:00 AM	75	20		0	0	Off Foot of San Jose St
2	11:20 AM	75	22	15600	0	0	Op Arsenal East End
3	11:35 AM	75	45	12500	0	0	E End Tallapiedra Wharf near Sewer
4	12:00 M	75	75	4200	0	0	Off San Nicholas Creek
5	12:20 PM	75	200	100	0	0	In San Nicholas Creek
6	12:50 PM	76	186	75	0	0	Matasiera Creek or Chavez River
7 a	2:30 PM	75	60	7500			Upper Harbor 200' E of Matasiera Creek
b	2:20 PM	75	45	12250			Upper Harbor 400' E of Matasiera Creek
c	2:10 PM	75	40	14500			300 N.E. of last point
d	1:40 PM	75	40	14500			250 N.E. of last point
e	1:20 PM	75	20	15200			250' N.E. of last point
f	3:00 PM	75	18	18500	6.67	94.9%	Near Steamship Maine
g	9/12			20300			Gulf stream 20 miles N. of Havana
h	10/12	65		19200			Off Punta Gorda West Coast of Fla
i	10/12	65		19200			Off Tampa, Fla

Tide Ebb
Tidal Range - 1 foot

(Exhibit [illegible] - ° 178)

EXAMINATION OF BALTIMORE HARBOR WATER

BY D. D. JACKSON

SAMPLE	TIME	TEMP	TURB	CHLORINE	DIS. OXYGEN Pts per Mil	DIS. OXYGEN % Sat	REMARKS
1	[illegible] 1.20 PM	46	35	4600	2.25 -	19.8%	End of City Pier
2	1.40 PM	46	30	4800	1.37 -	12.1%	Opp. Pier #5
3	2.40 PM	48	200	2100	3.30 -	29.0%	100' in Jones Falls Slip
4	3.30 PM	46	150	3000	2.33 -	20.3%	500' below Jones Falls Slip
5	4.00 PM	44	30	4650	4.18 -	35.9%	Off Fells Point
6	Dec 3, [illegible] 11.00 AM	41.5	18	4350	9.65 -	71.5%	Off Locust Point
7	12.30 PM	41	20	4300	10.29 -	84.4%	750' South of Ft. McHenry

High water - 3.40 PM
Wind - [illegible] about 15 miles per hour
Tidal Range [illegible]"
City [illegible] miles from Bay and 180 miles from Ocean

EXAMINATION OF BALTIMORE HARBOR WATER.

BY BALTIMORE SEWERAGE COMMISSION 1906, p 55

TIME - MARCH 20 - MAY [illegible], 1906

NO	LOCATION	WIND	BACTERIA	[illegible] PARTS PER MILLION
1	Foot of Calvert St	No wind	124,000	2.41
2	Mouth of Jones Falls		73,000	4.53
12	North End Middle Branch		11,500	3.18
6	Ferry Point	Windy	38,000	8.64
4	Off Lazaretto Point.	Windy	113,000	7.39
13	Mouth of Bear Creek	Windy	39,000	11.11
10	Mouth of Patapsco River.	High Wind	3,950	11.78
15	Back River Electric RR Bridge		950	13.90
16	Back River Todd Point.		750	11.02

[illegible]

EXAMINATION OF WASHINGTON HARBOR WATER

NO	TIME	TEMP	TURB	CHLORINE	DIS OXYGEN		REMARKS
					p.p.m.	% Sat	
1	4:00 PM	46	140	25	7.96	68.7%	Over Outlet
2	4:20 PM	45	90	10	9.65	77.8%	300' North of Outlet
3	4:25 PM	43	85	7.5	10.53	83.5%	2000 North of Outlet
4	4:45 PM	42	75	6.5	10.81	84.1%	[illegible] North of Outlet
5	5:00 PM	42	75	6.0	10.81	84.1%	8000 North of Outlet

(Exhibit I – cont'd)

EXAMINATION OF TAMPA HARBOR WATER

NO.	TIME	TEMP.	TURB.	CHLORINE	DIS. OXYGEN		REMARKS
					PPM per M	% Sat	
1	Nov. 1961 4:30 PM	65	40	14400	5.07	68.8%	Op. Seaboard Dock 20' from Lower Outlet
2	5:00 PM	65	37	13900	4.42	52.7%	300' from lower outlet in zone of influence
3	5:30 PM	60		3100	6.08	65.5%	50' from Upper Outlet

([illegible] J- 4/78)

EXAMINATION OF SAVANNAH HARBOR WATER

NO.	TIME	TEMP	TURB	CHLORINE	DIS OXYGEN Pts per M	DIS OXYGEN % Sat	REMARKS
1	2:30PM	45	90	240	9.41	77.9%	Foot of Broad St
2	3:30PM	46	150	360	9.65	81.2%	Just above Outfall
3	4:00PM	46	140	450	9.41	79.5%	Head of Canal
4	4:45PM	45	120	240	9.41	77.9%	Middle of River
1	8:00AM	55	55	220	7.80	73.4%	Bilbo Canal
2	8:15AM	53	75	80	9.81	90.1%	25' West of Bilbo Canal
3	8:30AM	50	55	70	9.65	85.2%	60' West of Bilbo Canal
4	8:35AM	50	55	60	9.81	86.7%	80' West of Bilbo Canal
5	8:40AM	50	40	55	9.73	86.0%	Middle of River
6	8:50AM	50	55	60	9.00	79.5%	250' below and E of Bilbo Canal
7	9:05AM	51	55	60			750' below and E of Bilbo Canal
8	[illegible]	50	50	60	9.33	82.4%	1000' below and E of Bilbo Canal
9	9:45AM	50	60	60	9.09	80.5%	1400' below Bilbo Canal
10	9:50AM	50	55	50			Middle of River
11	10:20AM	50-55	50-60	65	9.17	82.5%	Over Outlet

(Ex Rel. K-#178)

EXAMINATION OF JACKSONVILLE HARBOR WATER.

NO.	TIME	TEMP.	TURB.	CHLORINE	DIS. OXYGEN		REMARKS
					Pts per M.	% Sat.	
1	9/12 [illegible] 2:45 PM	55	40	3400	8.04	78.2%	30'N of Outfall at Foot of Main St
2	2:45 PM	54	55	3200-	6.67	64.1%	Over Outfall
3	3:00 PM	55	40	3400	8.04	78.2%	400' South of Outfall
4	3:15 PM	54	18	3800	9.17	88.4%	1000'W of Outfall and 600' from shore
5	3:30 PM	54	26	3500			1000'W of Outfall and 400' from shore
6	3:45 PM	54	30	3300			1000'W of Outfall and 200' from shore
7	4:00 PM	54	19	4200	9.17		1000' SW from Fairfield Outfall and 500' from shore
8	4:25 PM	55	40	3300			Catherine St. Sewer

River Section - 1000' x 40 and velocity 3 miles per hour

Horizontal Discharge in 20 feet of water
Boils up and spreads out on surface
The 15" Catherine St. Sewer discharges horizontally in 18' of water
The 8" Fairfield St. Sewer discharges horizontally in 7' of water
and these also boil up and spread out on surface

(Exhibit L - # 178)

EXAMINATION OF CHARLESTON HARBOR WATER.

NO.	TIME	TEMP.	TURB.	CHLORINE	DIS. OXYGEN Pts. per M.	DIS. OXYGEN % Sat.	REMARKS
1	11:55 AM	54	16	17600	8.04	90.8 %	Middle Cooper River Op Calhoun St
2 a	12:50 PM	68	80	4450	0	0	Op Old Calhoun St Sewer near Outlet
b	1:00 PM	65	70	6700	1.53	16.9 %	100' from Calhoun St Outlet
3	1:05 PM	55	18	17700			400' off So Battery in Ashley River Meeting St Drain not running
4	1:30 PM	55	28	16600			250' off Gaston Creek Ashley River

QUANTITATIVE PUTRESCIBILITY TESTS ON MUD.

(Exhibit M-#176)

NO	DATE	HARBOR LOCATION	TEMP	MOISTURE	LOSS ON IGNITION (dry)	PUTRESCIBILITY* (dry) 1 DAY	2 DAYS	3 DAYS	4 DAYS	REMARKS
1	2/12 1911	Baltimore. Off Jones Falls in 30' of water	48°F	55.3%	11.8%	1-220	1-450	1-670	1-830	Black Putrid Odor
2	3/12 1911	Baltimore. In Jones Falls Creek in 22' of water	48°F	54.4%	15.9%	1-220	1-810	1-955	1-1650	Black Putrid Odor
3	4/12 1911	Havana Harbor. San Nicolas Creek [illegible]	74°F	54.6%	29.3%	1-1100	1-1300	1-2200	1-2200	Black Putrid Odor
5	1/2 1911	Savannah Harbor	50°F	38.4%	12.1%	1-1	1-5	1-13	1-13	Clay Mud [illegible] Odor
6	5/9 1908	[illegible] Pond Mud	73°F	45.5%	23.4%	1-0	1-2	1-2	1-7	Slight Moldy Odor
7	5/9 1908	East Meadow Brook Mud	76°F	38.0%	32.4%	1-0	1-1	1-2	1-2	Earthy Odor
8	7/9 1908	Mt Prospect Reservoir	75°F	51.0%	20.8%	1-1	1-4	1-6	1-6	Earthy Odor
		-NEW YORK HARBOR-								
9	2/8 1912	600' N of Gov. I. on line between Gov. I. and Ellis I.	32°F	53.4%	10.8%	—	1-560	—	1-850	Black, Putrid Odor
10	2/8 1912	600' S.W. of Buoy #16, in 24' of water	32°F	35.1%	4.3%	—	1-160	—	1-310	" "
11	2/13 1912	800' NW of Buoy #3, in 14' of water	32°F	44.4%	5.9%	—	1-180	1-540	1-720	" "
12	2/13 1912	1500' NE by E of Robbins Reef Light, in 18' of water	32°F	36.5%	4.4%	—	1-160	—	1-400	" "
13	2/13 1912	2000' from Robbins Reef Light, on line with Gov. I., in 28' of water	32°F	52.8%	8.6%	—	1-630	—	1-740	" "
14	2/13 1912	600' from Liberty I. on line with Buoy #16, in 10' of water	32°F	57.6%	8.8%	—	1-710	1-940	1-1290	" "

*Dilutions made with aerated distilled water, containing 9 parts per million of Oxygen

62-69, which show the results of analysis of samples of the
61 harbor waters made by D. D. Jackson and collected by your Committee, care having been taken in this case to select results which represent the normal harbor water, or water from those parts least affected by sewage pollution.

At New York, the chemical data were obtained from the report of the Metropolitan Sewerage Commission 1910, except the putrescibility tests on mud, which were made in the laboratory of Mr. Nicholas S. Hill, Jr., upon samples collected from New York Harbor on February 8, 1912, and February 13, 1912.

(Here follow tables marked F, G, H, I, J, K, L, and M, pages 62, 63, 64, 65, 66, 67, 68, and 69.)

70

APPENDIX II.

Giving Basic Data and Explanation of the Method of Determining Total Population, Tributary Population, Domestic Sewage Flow, Manufacturing Wastes, Ground Water Infiltration, and Total Sewage Flow.

Table No. 2, Facing Page 29.

A. The Population Figures, Col. 2, have been obtained as follows:

For Havana, from the statement of Mr. H. E. Hyde of the Obras Publicas, Havana.

For Baltimore, from the United States Census of 1910.

For New York, from figures given on Page 13 of "Basic Physical Data Relating to the Metropolitan and Passaic Valley Sewerage Districts," as follows:

	1910.	1940.
Total Population in Metropolitan District..	6,424,530	12,846,560
From this total is to be subtracted:		
1st. The population tributary to Long Island Sound	33,648	81,000
2nd. The population tributary to Lower New York Bay	345,403	966,000
3rd. 16 per cent of the population tributary to the Passaic, Hackensack and Newark Bay—this proportion of the sewage in Newark Bay has been estimated by the Central Committee as flowing into the Lower Bay, through the Arthur Kill, 16%	31,300	78,438
Total Deductions	410,351	1,125,438
	6,014,179	11,721,122

71 The following Table No. 4 shows that the estimate of a population of 12 million within the Metropolitan District in 1940 is very conservative.

Table No. 4.

Comparison of Population Estimated, City of New York.

	1900.	1910.	1940.
*John R. Freeman.......	3,437,202	4,766,883	7,652,000
*Metropolitan Sewerage Commission	....	....	8,666,100
Central Committee of Experts State of N. Y.....	....	....	9,000,000
*N. Y. Telephone Co.	....	....	8,747,000
*Board of Water Supply ..	....	....	9,258,000
*Public Service Commission	....	....	13,700,000

For Washington, from the statement of Mr. Sawtielle of the Board of Health, Washington.

For Tampa, Savannah, Jacksonville and Charleston, from the statement of local engineers checked against the figures of the United States Census of 1910.

For Boston, as follows, from figures published in the report of the Boston Metropolitan Water & Sewerage Board 1910.

Table No. 5.

	Contributing.	Total.
N. Metropolitan District	465,000	524,000
S. " "	230,000	360,000
Boston Main Drainage District	470,000	**487,000
	1,165,000	1,371,000

B. The Population Contributing Sewage. Col. 3, has been estimated as follows:

For Havana from the statement of Mr. H. E. Hyde, of the Obras Publicas, Havana.

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* All estimates marked thus made before 1910 census were available.

** Deducting 183,000 population of Boston tributary to the Metropolitan Sewer System, from the 1910 Census population of Boston. (670,000—183,00 = 487,000).

72 For New York, by assuming 80 per cent of the total population to be connected to sewers.

For Baltimore, as follows:

Total area of the city...........		19,200	acres
Area of the densely built up portion of the city, 50%, or......		9,600	"
Population	558,000		
Density .... $\frac{558,000}{9600}$	=	58	per acre
Area tributary to North West Harbor		5,000	acres
Population in this area 5000x58..	=	290,000	
50% assumed connected to sewers 290,000 x 50%	=	145,000	population contributing sewage.

For Washington, by assuming 90 per cent of the total population to be tributary to sewers connected with the main sewage outfall.

For Boston, see Table No. 5, Page 71.

For Savannah, estimate of Mr. John W. Howard, City Engineer of Savannah.

For Jacksonville, estimate of Mr. R. N. Ellis, Supt. Water Electric Light and Sewers, Jacksonville.

For Charleston, Dr. J. M. Green, Health Officer, Mr. Dunlop of City Engineer's office and Mr. J. M. Diven, Supt. of the Water Company. The total number of houses is approximately 9,000, of which 6,000 have privy vaults or dry closets. There are probably 3,000 houses connected to the sewers and the total population, $59,000 \times \frac{3000}{9000} = 19,700$ population contributing sewage.

(Here follows table marked Exhibit N, page 73.)

(Exhibit N #178)

- TABLE Nº 6. -

GROSS AND PER CAPITA CONSUMPTION OF WATER AT VARIOUS PLACES WITHIN THE METROPOLITAN DISTRICT OF NEW YORK.

Place	Per Capita Consumption (Gals. Daily)	Population	Total Consumption (Million Gals. Daily)
(1)	(2)	(3)	(4) = (2) × (3)
Greater New York	114.0	4,766,883	545.0
Yonkers	103.0	79,803	8.2
Mt. Vernon	100.0	30,919	3.1
Newark	98.0	343,994	33.7
Jersey City	150.0	267,779	40.1
Paterson	80.0	125,600	10.0
Hoboken	114.0	70,324	8.0
Elizabeth	82.0	73,409	6.0
Passaic	79.0	54,773	4.3
Harrison	124.0	14,498	1.8
Kearney	102.0	18,659	1.9
East Orange	90.0	34,371	3.1
Bayonne	118.0	55,545	6.5
White Plains	80.0	15,045	1.2
Totals		5,961,602	672.9
Average	112.5		

Exhibit D.--#178)

DATA ON THE INFILTRATION OF GROUND WATER INTO SEWERS.

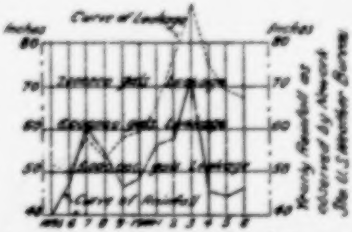

Diagram showing relation between rainfall and leakage into municipal sewage works as computed from records of flow of Union Outlet sewer from Orange, Montclair, Glen Ridge, and Bloomfield, N. J.

Passaic Valley Sewerage Comm.
Report of Dec. 1907, page 15.

TABLE SHOWING PROBABLE LEAKAGE OF GROUND WATER INTO SEWERS OF ORANGE, MONTCLAIR, BLOOMFIELD & GLEN RIDGE FROM 1895 to 1906.

Date	Probable Leakage in Mill. Gals/Day	Probable Leakage Gals/Capita per day	Rainfall Inches per Year.
1895	5.2	87	49.83
96	5.0	84	46.68
97	5.82	97	60.69
98	5.27	88	54.17
99	5.84	97	45.68
1900	5.89	98	48.40
01	6.48	108	55.84
02	7.58	126	56.79
03	9.00	150	70.90
04	7.48	125	44.80
05	6.91	115	43.72
06	6.70	112	45.63
Avr.	6.43	107	51.14

Assumed population of 60,000 based on proportional population connected to sewers is the same (80%) in 1910 as in 1906.

Table taken from Passaic Valley Sewerage Commission report of December 1907.- Page 15.

(Schedule P - 9 (B))

Data on Infiltration of Ground Water into Sewers

	Place	Size of Sewer	[illegible]	[illegible]	[illegible]	[illegible]	Total Leakage in gals per day	Remarks
1	Boston, Mass	6"-36"	107		40000	50	5400000	Before any connect. to sewer
2	Mass. State	—	700		80000	100	56,000,000	Densely populated section. [illegible]
3	Kalamazoo, Mich			84%				Before any connect. to sewer
4	Norfolk, Va			40%		100		
5	Schenectady, N.Y			3%				Wet ground and quick sand
6	Canton, O		11		84500	*.46	12000	
7	Taunton, Mass	24"		20%				Passing through swamp
8	North Brookfield, Mass	10"	0.2		17000	71	3400-3500	
9	Rogers Park, Ill	6"	1.7		1240	*.2	2100	Bag sockets and careful [illegible] to main line
10	Brockton, Mass		16		25000	31	400,000	
11	Altoona, Pa	27"	1.3		36814	*.45	47,101	
		30"	0.6		86,570	*.145	52,352	
		[illegible]	6.46		245,000	*.462	252,948	[illegible]
12	East Orange, N.J		20		32,400	*.43	636,200	[illegible]
13	East Orange, N.J		2.6		8,700	*.16	217,300	
14	Joint Trunk Sewer		100	40%	20000	90	2700000	Glacial drift and quicksand
15	Bo. of Essex, Orange, Montclair and Glen Ridge					107	6,430,000	Average for years of 1896 to 1906

[illegible]

74 For Tampa, from the estimate of Mr. F. F. Warner, City Engineer of Tampa.

C. The Daily per Capita Volume of Domestic Sewage, Col. 5, is estimated as follows:

For Havana, it is assumed to be equal to the daily per capita consumption of water, as stated by Mr. H. E. Hyde of the Obras Publicas, Havana.

For Baltimore, it is assumed to be equal to the daily per capita consumption of water as shown in the records of the Baltimore City Water Department.

For New York, Table No. 6, opposite, shows the daily per capita consumption of water in various communities within the Metropolitan Sewerage District. The average daily per capita consumption of water is shown by this table to be 112.5 gallons; 113 gallons per capita daily has been assumed to be the volume of domestic sewage to be expected within the district.

It is a recognized fact that the per capita consumption of water increases as the total population increases, and a daily sewage flow of 130 gallons per capita has been estimated for the New York Metropolitan District in 1940.

For Tampa, 125 gallons per capita daily is assumed as a conservative estimate of the sewage discharged by a city of the size and character of Tampa.

For Savannah, Jacksonville and Charleston, the volume of sewage per capita daily is assumed to equal the daily per capita consumption of water which has been computed from data supplied by Mr. John W. Howard in Savannah, Mr. R. N. Ellis in Jacksonville, and Mr. J. M. Diven, Supt. of the Charleston Light and Water Company.

75 For Washington and Boston, the method of determining the amount of domestic sewage is included in the explanation of the total volume shown in Col. 8.

D. The Volume of Manufacturing Waste Derived from Private Water Supplies, Col. 6, has been estimated from careful consideration of the manufacturing and water supply conditions in the several cities.

E. Infiltration of Ground Water, Col. 7.

The curve and tables following Pages 76-77, show that ground water may leak into a sewer in quantities ranging from 2 to 442 gallons per day per capita of population served by the sewer. From a careful study of the tables, 50 gallons per capita daily has been assumed to be a fair average value.

In the case of Washington and Boston no infiltration is shown, as it is included in the volume of sewage shown in Col. 8.

(Here follow tables marked Exhibits O and P, pages 76 and 77.)

78 **F. The Total per Capita Daily Volume of Sewage, Col. 8.**

For Washington, the volume of 218 gallons per capita daily has been computed from the records of sanitary sewage and storm water pumped to the main sewer outlet during the year 1910-1911. See "Report of the Operations of the Engineer Department of the District of Columbia, for the fiscal year ending June 30, 1911," page 156.

For Boston, the volume was estimated as follows from data presented in the eport of the Metropolitan Water and Sewerage Board for 1910."

Sewer System.	Outlet.	Flow in gallons daily.
North Metropolitan,	Deer Island	60,000,000
South "	Nut or Peddock's Island	40,000,000
*B. M. Drainage	Moon Island	105,000,000
		205,000,000

* Mr. X. H. Goodnough, on Page 416 of the Report of the Mass. State Board of Health, 1905, states the discharge from Moon Island to be 100,000,000 gallons daily in 1905. Increasing this volume in proportion to the increased population, it becomes 105,000,000 gallons in 1910. In 1905 the population contributing sewage to the Boston Main Drainage System, having its outlet at Moon Island, was, 615,000—156,000 = 459,000. (See Report of Metropolitan Water and Sewerage Board, 1905, Page 144.) 100,000,000 ÷ 459,000 = 223 gallons per capita. 223 x 470,000 = 105,000,000. (See Table 25, Page 71).

	Sewage per capita.	
	Contributary population.	Total population.
North Metropolitan	129.0 G. D.	114.5 G. D.
South "	174.0 " "	111.0 " "
Boston Main Drainage	233.0 " "	218.0 " "
Average	175.0 " "	148.0 " "

(Here follows table marked Ex. Q, page 79.)

-TABLE Nº 7.-

ESTIMATED TOTAL DRY SLUDGE OR SUSPENDED MATTER IN VARIOUS SEWAGES

(Exhibit Q-#178)

Place	Parts per Million	Grams per capita daily	Tons per million gallons	Tons per 1000 population per annum
	(1)	(2)	(3)	(4)
* Framingham, Mass.	289	80	1.20	32
* Gardnier, Mass.	102	38	0.42	13
* Marlboro, Mass.	68	29	0.28	12
a Brockton, Mass.	195	26	0.82	10
* Worcester, Mass.	360	202	1.50	81
b Columbus, Ohio	215	98	0.89	39
a Providence, R.I.	397	141	1.67	56
c Philadelphia, Pa	180	—	0.76	—
a Boston, Mass.	149	125	0.63	50
d Paterson, N.J.	144	68	0.60	27
Av. of last six largest cities	240	127	1.01	50

* From paper by Geo. W. Fuller, Trans. Am. Soc. C.E., Vol. LIV, page 166

a "Sewage Disposal" Kennicutt, Winslow, and Pratt - pages 6 and 7.

b Report on Sewage Purification at Columbus, Ohio - 1905 - page 34.

c Report of Bureau of Surveys, Comprising Work at Sewage Experiment Station 1911 - page 200.

d Report on Sewage Disposal - Paterson, N. J. 1906 Appendix #1 - page 18.

TABLE No 8.
RATIO OF TOTAL SOLIDS
TO
SUSPENDED MATTER IN SEWAGES.

Place	Population	Parts per Million		Ratio
		Total Dry Solids	Suspended Matter	
(1)	(2)	(3)	(4)	(5)
Framingham, Mass	12,948	601	289	2.08
Gardnier. Mass.	14,699	287	102	2.81
Marlboro. Mass	14,579	300	68	4.41
Brockton, Mass	56,876	818	195	4.14
Boston. Mass.	671,000	—	149	—
Philadelphia, Pa	1,549,000	—	180	—
Paterson, N.J.	126,000	319	144	2.14
Providence, R.I	224,000	1715	397	4.29
Worcester. Mass.	146,000	908	360	2.33
Columbus, Ohio	182,000	1026	215	4.77
Aver of last four-largest cities				3.38

(Exhibit R-#178)

(Exhibit S
p. 178)

TABLE Nº 9
RATIO OF
WET SLUDGE AND DRY SOLIDS
DEPOSITED PER MILLION GALLONS OF SEWAGE.

Where Collected	Authority	Tons of Wet Sludge	Tons of Total Dry Solids	Ratio
(1)	(2)	(3)	(4)	(5)
In Grit Chambers	Report on Columbus, Ohio, Sewage Purification, - 1905 - page 86.	2.27	0.29	7.83
		1.61	0.28	5.75
In Sedimentation Tank	Report on Columbus, Ohio, Sewage Purification; - 1905 - page 101	2.97	0.36	8.25
		3.29	0.38	8.66
		3.22	0.33	9.76
In Sedimentation Tank	Report of Bureau of Surveys on Sewage Experiment Station, Philadelphia Pa. 1910 - Table #6 - Page 38.	4.28	0.428	10.00
		3.56	0.443	8.00
			Average	8.32

APPENDIX III.

Basic Data for Estimating Tons of Wet Sludge per Million Cubic Feet of Sewage.

Table No. 7 gives the estimated total suspended matter in various sewages. The average of the six largest cities given in Col. 4 is 50 tons per 1,000 population per annum, which is the figure used in the report.

Table No. 8 gives the ratio of total dry solids to suspended matter in various sewages. The average ratio of the four largest cities is 3.38.

Table No. 9 gives the ratio of wet sludge to total dry solids, the average being 8.32.

We have assumed, therefore, 50 tons of suspended matter per 1,000 population per annum $\times$ 3.38 $\times$ 8.32 = 50 $\times$ 28.12 = 1,406 tons of wet sludge per 1,000 population per annum. Assumed population for New York—6,000,000 gross tons sewage sludge in 1911 = 6,000 $\times$ 1,406 = 8,436,000 tons, or approximately 9,540,000 cubic yards.

(Here follow tables marked Exhibits R and S, pages 81 and 82.)

83 APPENDIX No. IV.

Laboratory Methods and Experiments.

Although the methods employed by your committee in the examination of the water and muds from the various harbors considered are all well known and in general use, it is deemed advisable to give a brief description of them, together with a description of one or two studies made during the investigation.

The usual examination consisted of the determination of the temperature, dissolved oxygen, salinity and turbidity of the water and degree of putrescibility of the mud. A study was made to determine the relative value of different methods for the determination of dissolved oxygen, and a series of tests was made to determine the effect of varying quantities of nitrites on the accuracy of the "Winkler" method for the determination of dissolved oxygen.

Dissolved Oxygen.

The amounts of dissolved oxygen in the waters of New York Harbor have been taken from the figures presented by the Metropolitan Sewage Commission and given in their report. The method employed by that commission for the determination of dissolved oxygen was the "Levy" method.

The samples of water examined from harbors other than at New York were collected with the apparatus carried by your committee, and the quantity of dissolved oxygen was determined by both the "Levy" and the "Winkler" methods. These methods are described in detail at another point in this appendix. The results of these examinations showing the oxygen dissolved in the various harbor waters are given in the tables on pages 62 to 68.

84 Salinity.

The salinity of the various harbor waters examined was ascertained by the determination of the amount of chlorine present in the water. The chlorine was determined according to standard methods by titration with a solution of silver nitrate (2.4 grams per liter) using potassium chromate as an indicator.

Turbidity.

The turbidity of the water in the various harbors examined was determined by use of the United States Standard Turbidity Rod. In some few instances when no rod was available the turbidity was taken with a rule graduated in inches, and the reading calculated to parts per million by aid of the standard table. The turbidities at various points in the different harbors are shown on the tables pages 62-68.

Putrescibility of Muds.

The method used in determining the putrescibility of the mud from the bottom of the various harbors is that devised by one of this committee (D. D. Jackson) and W. A. Horton and published in the Journal of Industrial & Engineering Chemistry, June 1909 and which depends upon the decoloration of an organic dye by putrescible substances in the absence of available oxygen. The method as used is as follows:

Solutions of mud in various proportions are made by adding a definite weight of the wet mud to varying quantities of distilled water saturated with air at the room temperature (about 20° C.). One c. c. of methylene green (½ gram per liter) is added to each liter of the various dilutions. An eight ounce bottle is filled with the dyed solution of mud and a rubber stopper fitted with a short tube and rubber bulb, also filled with the mud solution, is
85 inserted in such a way that no air bubbles are enclosed. The water in the rubber bulb is then forced out, leaving the bulb collapsed. The bottle is now placed in the 37° incubator and allowed to remain at that temperature for four days. As fast as the solution in the bottle expands, because of the increase in temperature, the increase fills the rubber bulb. In this manner no solution escapes and no air is brought in contact with the solution after the test begins.

As soon as the oxygen dissolved in the solution is consumed by the organic matter in the mud, the dye present is attacked and the color disappears. This disappearance of color therefore indicates a putrescible condition and a higher dilution must be examined.

A sample of the wet mud is dried at 100° C. for one hour and the percentage of moisture determined. From this the actual weight of dry mud used may be determined and the correct degree of putrescibility may be figured.

The samples taken in New York Harbor were collected with a piece of apparatus shaped like a mushroom anchor weighing about ten (10) pounds and having a head twelve (12") inches in diameter and six (6") inches deep. The mud was obtained by dragging this anchor on the bottom of the harbor for a few feet and then bringing it to the surface. The results of these tests are given in the table on page 69, of Appendix I.

A Comparison of Various Methods for the Determination of Dissolved Oxygen in Sea Water.

Considerable discussion has arisen recently concerning the relative accuracy of various methods for the determination of dissolved oxygen in sea water. In order to convince ourselves on this
86 point, studies were made comparing the various methods.

Apparatus.—The apparatus used in the collection of samples of water from New York Harbor consisted of a container holding three separatory funnels of about 300 c. c. capacity and having

a small bulb in the stem and a two liter bottle. The container was weighted so that it would sink readily. The funnels and large bottle were so connected that the water was taken from a common point and passed through the funnels into the bottle. When the large bottle was filled the water in the small funnels had been changed several times thus securing a uniform sample free from contact with the air.

As soon as the container was brought to the surface the filling tubes were removed and stoppers inserted in the funnels, care being taken that no air should remain in the funnel. The tests were made as soon as the samples reached the laboratory which was not more than ten minutes from the time they were taken.

One funnel was used in making a test by the "Winkler" method and the other two were used in making a test by either the "Levy" or "Letts-Adeney" methods.

The methods used in making the determination of oxygen dissolved in sea water are known as the "Winkler" method, the "Levy" method and a third method referred to as the "Letts-Adeney" method and described in the Fifth Annual Report of the Royal Sewage Commission, Appendix 6, Pages 221-224.

Briefly described the methods are as follows:

Winkler Method.—The stopper is removed from one of the full separatory funnels and two c. c. of manganeous sulfate solution (48 grams to 100 c. c. of water) and two c. c. of sodium hydrate and potassium iodide solution (360 grams of hydrate and 100 grams of iodide to 1000 c. c. of water) are delivered at the bottom of
87 the funnel. The stopper is again inserted and the solutions thoroughly mixed. After standing for five minutes in the inverted funnel, four (4) c. c. of sulfuric acid (1:1) are admitted to the funnel through the stem. The acid dissolves the precipitate formed. The contents of the funnel plus the liquid replaced by the acid is rinsed into a half liter bottle and titrated with $\frac{N}{40}$ solution of sodium thiosulfate using five (5) c. c. of starch solution near the end of the titration as an indicator.

The calculation of the results is made from the formula as given on page 76 of the Report of the Committee on Standard Methods.

Oxygen in parts per million $= \frac{200\ N}{V}$ where "V" is the capacity of the funnel, in c. c., less the volume of manganeous sulfate and potassium iodide solution added (less four c. c.). "N" is the number of c. c. $\frac{N}{40}$ sodium thiosulfate solution used in the titration.

Levy Method.—Six (6) c. c. of ferrous sulfate solution (48 grams of salt and five (5) c. c. of sulfuric acid per liter) and four (4) c. c. of sodium carbonate solution (200 grams per liter) are introduced at the bottom of the separatory funnel. The stopper is inserted and

(Exhibit T #178)

RELATIVE RESULTS OBTAINED
WITH
LETTS-ADENEY AND THE WINKLER METHODS FOR THE DETERMINATION
OF
DISSOLVED OXYGEN IN THE WATERS OF NEW YORK HARBOR

Date	Temp. °C	Tide	Chlorine	Nitrites	Oxygen Dissolved		% Saturation	
					Letts-Adeney	Winkler	Letts-Adeney	Winkler
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1-31-12	0	Flood	13,200	.016	11.73	10.15	94.29	81.59
2-1-12	0	"	12,900	.014	4.59	8.52	36.75	68.19
2	0	"	13,500	.016	20.40	10.72	164.65	86.52
5	0	Ebb	12,300	.018	12.75	10.43	101.27	86.02
6	0	"	15,600	.020	7.33	10.29	61.70	86.62
8	0	"	14,800	.011	—	10.37	—	85.23

(Exhibit U.
#178)

RELATIVE RESULTS OBTAINED
WITH
THE LEVY AND THE WINKLER METHODS FOR THE DETERMINATION
OF
DISSOLVED OXYGEN IN THE WATERS OF NEW YORK HARBOR

Date	Temp. °C	Tide	Chlorine	Nitrites	Oxygen Dissolved		% Saturation	
					Levy	Winkler	Levy	Winkler
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1-9-12	2	Flood	12,350	.016	11.22	9.16	90.66	73.75
10	0	"	8,300	.016	9.94	9.18	74.03	80.16
11	0	Ebb	11,500	.015	12.24	10.65	96.23	83.73
12	0	"	13,850	.010	12.24	10.70	99.19	86.71
13	0	Flood	13,000	.011	11.22	10.37	89.98	83.16
15	0	"	14,100	.016	9.69	9.30	78.84	75.67
16	-2	"	13,300	.016	15.30	10.68	123.19	85.18
17	0	"	12,100	.020	11.73	9.55	94.53	75.99
18	0	"	14,000	.012	11.22	10.61	93.75	88.70
19	0	"	15,500	.021	10.71	9.37	88.81	77.28
22	0	Ebb	13,000	.016	10.71	9.44	90.53	79.79
23	0	"	13,100	.014	10.71	9.30	86.03	74.70
24	0	"	12,500	.018	11.22	7.88	89.33	67.74
25	0	"	13,500	.016	9.18	9.23	74.09	75.30
26	0	"	13,000	.030	9.18	9.59	73.62	76.90
29	0	Flood	13,800	.018	12.24	9.73	99.19	78.85
30	0	"	13,500	.020	11.73	9.66	94.67	77.99
2-16	19	"	13,200	.018	6.63	6.58	81.25	80.27

the contents of the funnel thoroughly mixed. The funnel is then inverted and allowed to stand for five minutes. Ten (10) c. c. of sulfuric acid (1:1) are then admitted to the funnel through the stem. As soon as the precipitate is dissolved and the solution is colorless, the contents of the funnel are rinsed into a half liter bottle and titrated with standard potassium permanganate solution, made by dissolving 5.638 grams of salt in 1000 c. c. of water. One (1) c. c. of this solution is equivalent to one (1) c. c. of oxygen under normal conditions of temperature and pressure.

68 A blank test to determine the value of the ferrous sulfate solution is made by repeating this method with another funnel, but adding the sulfuric acid before the ferrous sulfate or sodium carbonate.

The result is calculated by subtracting the number of cubic centimeters of potassium permanganate required in the titration of the sample, from that required by the blank. This number divided by the volume of the funnel and multiplied by 1000 equals the number of c. c. of oxygen per liter of water and this multiplied by 1.434 equals parts per million.

Letts-Adeney Method.—Seven (7) c. c. of the sample are removed from the separatory funnel and five (5) c. c. of ferrous sulfate solution (48 grams per liter) are introduced at the bottom of the funnel. Strong ammonia is added until the funnel is full and the stopper is replaced, care being taken that no bubble of air is enclosed. The liquids being of different specific gravities the ferrous sulfate solution remains at the bottom of the funnel and the ammonia is at the top. When the funnel is agitated the liquids mix and a precipitate is formed. The funnel is inverted and allowed to stand for five minutes. Ten (10) c. c. of sulfuric acid (1:1) are then applied through the stem and when the precipitate has dissolved the whole is rinsed into a half liter bottle and titrated with standard potassium bichromate solution made by dissolving 8.7906 grams of salt in one (1) liter of water. Each c. c. of this solution is equivalent to one cubic centimeter of oxygen at normal temperature and pressure. The titration is made using potassium ferricyanide as an indicator.

(Here follow tables marked Exhibits T and U, pages 89 and 90.)

91 A blank test is made using a separatory funnel in the same manner as above but adding the sulfuric acid before the ferrous sulfate ammonia.

The result is calculated to parts per million by the same method as that used in the "Levy" method.

Comparison of Results.

Twenty-four (24) tests were made in the study to determine the relative accuracy of the various methods for the determination of dissolved oxygen. Eighteen (18) were made comparing the "Winkler" and "Levy" methods and six (6) comparing the "Winkler" with the "Letts-Adeney" method. The results expressed in parts per million and in per cent saturation together with the temperature, condition of tide, and amount of nitrite and chlorine present are recorded in the accompanying table.

The water used in these tests was taken from the East River at the outer end of Pier 15. This sampling point was chosen in view of the fact that a large sewer empties into the river under this pier, and the water at this point would therefore contain a high amount of organic matter.

It will be noted from the table of results that with the exception of two tests the "Levy" method yields higher results than does the "Winkler." Sometimes the "Levy" method produces a result so high as to indicate super-saturation. This seems highly improbable even at the low temperature, when the high amount of organic matter known to be present is taken into account.

92 The average difference in the per cent saturation between the two methods is 12.42%. The average difference expressed in parts per million is 1.59.

The effect of slight variations in the titration by either method may best be shown in the form of a table as follows:

Method.	Volume of reagent used.	Equivalent to parts per M.	% saturation at 0°C 13,300 parts per M., of chlorine.	Difference in % saturation, due to 0.1 c.c.
Winkler	14.1	10.01	80.59	0.56%
	14.0	0.94	80.03	
Levy	2.2	11.22	90.35	4.12%
	2.1	10.71	86.23	

It also appears that one (1) part per million corresponds to a difference of 8.23% in percentage of saturation with the conditions of temperature and salinity under which these tests were made. With higher temperature conditions the difference would be even greater.

The difference between the results obtained with the Winkler and Letts-Adeney methods are greater than the difference between the Winkler and Levy methods. Difficulty was also encountered in obtaining a satisfactory end point in several tests so that it was concluded that nothing was gained by using this method.

EFFECT OF NITRITES

ON THE

ACCURACY OF THE WINKLER METHOD FOR THE DETERMINATION OF DISSOLVED OXYGEN

A. DISTILLED WATER				B. N.Y. HARBOR WATER			
Nitrite Present	Dissolved Oxygen	Nitrite Present	Dissolved Oxygen	Nitrite Present	Dissolved Oxygen	Nitrite Present	Dissolved Oxygen
.000	9.29	.015	9.18	.015	7.47	.105	7.98
.001	9.24	.020	9.17	.025	7.36	.115	7.83
.002	9.26	.030	9.28	.035	7.62	.165	7.80
.003	9.23	.040	9.16	.045	7.84	.215	7.71
.004	9.24	.050	9.19	.055	7.51	.315	7.77
.005	9.24	.100	9.26	.065	7.63	.415	8.13
.006	9.23	.200	9.16	.075	7.49	.815	8.86
.007	9.17	.400	9.47	.085	7.83	1.015	9.26
.008	9.28	.800	10.24	.095	7.61		
.009	9.09	1.000	11.70				
.010	9.31	4.000	18.50				
.012	9.36						

Results expressed in Parts per Million.

Distilled Water saturated with oxygen at 15°C Contains 9.37 parts per Million.

Results expressed in Parts per Million.

Nitrite originally present = .015
Chloride present = 13,000

Sea Water Saturated with oxygen at 15°C Contains 8.6 parts per Million.

The results and conclusions of the Central Committee are based on determinations made by the Levy method. It would seem from our experiments, made with these methods, that the true percentage of dissolved oxygen may be lower than that deduced by the Metropolitan Sewerage Commission from determinations by the Levy method.

(Here follows table marked Exhibit V, page 93.)

94 *The Effect of Nitrites on the Accuracy of the Winkler Method for the Determination of Dissolved Oxygen.*

Several investigators have stated that the accuracy of the Winkler method for determination of dissolved oxygen was impaired when nitrites were present. In order to determine the extent of the effect of nitrites on this method, a series of tests was made, using distilled water charged with oxygen, and salt water as taken from New York Harbor.

This salt water as collected contained 13,200 parts per million of chlorine and .015 parts per million of nitrites. It also contained 7.47 parts per million of dissolved oxygen. Standard solutions of potassium nitrite were prepared of such strengths that one (1) c. c. diluted to one hundred (100) c. c. increased the nitrite present by 1.000, 0.100, 0.010 or 0.001 parts per million. Since the salt water used in the tests had .015 parts per million of nitrites ordinarily present, it was impossible to determine whether this initial amount was sufficient to effect the determination of dissolved oxygen. In order to settle this question, distilled water free from nitrites and aerated until it was practically saturated with oxygen, was used for a second series of determinations.

The results of these tests are given in tabulated form in the table on page 93. It will be seen from this table that nitrites present in quantities of less than 0.500 have no effect on the determination of dissolved oxygen by the Winkler method. Since this quantity of nitrites is very rarely, or never present in waters to be examined for dissolved oxygen it appears from the studies here described that the Winkler method may generally be used without regard for the composition of the water.

THE PEOPLE OF THE STATE OF NEW YORK,
COMPLAINANTS,

vs.

STATE OF NEW JERSEY ET AL.

HERE FOLLOW COMPLAINANTS' EXHIBITS Nos. 179 and 180.

JAMES D. MAHER,
Commissioner.

Complainants Exhibit No. 179
James D. Maher
Commissioner

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TABLE

PAST, PRESENT AND ESTIMAT-
BRONX VALLEY SEWER
AND
CIVIL DIVISIONS LYING WHOLLY OR PARTLY

Name of Civil Division	Period Considered	Population at Earliest Date Named in Col #2	Population at Latest Date Named in Col. #2
(1)	(2)	(3)	(4)
City of Yonkers	1880-1910	18,892	79 803
City of Mt Vernon	1880-1910	4 586	30 919
Town of Eastchester	1900-1910	3,039	6 422
Town of Scarsdale	1880-1910	614	1 300
Town of Greenburgh including portion of White Plains Village	1880-1910	8,934	23 193
Town of White Plains excluding White Plains Village	1890-1910	689	1 141
Village of White Plains portion of, lying in White Plains Town	1880-1910	2,381	13 904
Total or Average			156 682
Bronx Valley Sewer Assessment Area	1906-1910	32,212	49,000
Borough of Bronx	1867-1905	32,500	305 000
Borough of Queens	1860-1912	32,903	310 523

221 * } 13.5 * } These figures indicate growth for period in col. #2 and are presented for purposes of comparison

Nº12.–

ED FUTURE POPULATION
ASSESSMENT AREA
OF THE
WITHIN THE ASSESSMENT AREA

Complainant's Exhibit No. 180
James D. Maher
Commissioner

Population 1920	Population 1930	Population 1940	Population 1950	Average Per Cent of Annual increase based on initial population given in Col 3
(5)	(6)	(7)	(8)	(9)
122 183	175 652	242 199	334 178	23.8
41 190	51 460	61 730	72 000	21.0
11 201	20 334	35 988	53 982	33.5
2 078	3 627	6 337	10 965	24.1
31 037	42 801	59 357	81 972	11.7
1 656	2 820	4 673	7 277	15.9
22 402	31 032	39 662	48 052	27.4
231 747	327 726	449 946	608 426	20.8
96 [illegible]46	143 072	214 188	303 163	19.11
				22.1 * 13.5 *

THE PEOPLE OF THE STATE OF NEW YORK,
COMPLAINANTS,

vs.

STATE OF NEW JERSEY ET AL.

HERE FOLLOWS COMPLAINANTS' EXHIBIT No. 181.

Shellfish Investigation in Raritan Bay by New York State Department of Health.

JAMES D. MAHER,
Commissioner.